Care or Neglect?

Evidence of Animal Disease in Archaeology

Edited by László Bartosiewicz and Erika Gál

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Proceedings of the 6th meeting of the
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Foreword

The Animal Palaeopathology Working Group is an autonomous organisation within the International Council for Archaeozoology (ICAZ). Its members are specialised in the reconstruction of past animal health, typically using evidence from excavated animal remains. The 6th meeting of this loosely defined group of scholars was organised in Budapest between 26–29 May 2016. The present volume comprises the proceedings resulting from the lectures, poster presentations and lively exchange of ideas during the meeting.

The conference was dedicated to the memory of Sándor Bökönyi (1926–1994), former director of the Archaeological Institute of the Hungarian Academy of Sciences (1981–1993) on the 90th anniversary of his birth. A fresh graduate in veterinary sciences working in the Hungarian National Museum, Bökönyi established modern archaeozoological research in Hungary in 1950. In his analyses, he represented a fresh perspective combining veterinary expertise with archaeological reasoning. This period represented the heyday of classical archaeozoology in Central Europe. Bökönyi was a founding member of ICAZ and co-hosted with János Matolcsi, the 1971 conference in Budapest that marked the beginning of the organisation. At the time, ICAZ was committed to facilitating academic exchange between archaeozoologists working in the politically divided western and eastern halves of Europe. Bökönyi's best known book, the *History of Domestic Mammals in Central and Eastern Europe*, was a contribution to the unfolding international cooperation in our field.

During the editing works of this volume we received the news that another key figure in animal palaeopathology, Don Brothwell (1933–2016) sadly passed away in September 2016. We therefore decided to pay tribute to his oeuvre as well. Brothwell was an archaeologist and anthropologist by training, and specialist in human palaeoecology and environmental archaeology. Having spent the first 16 years of his career at the University of Cambridge and the British Museum (Natural History), Brothwell was appointed senior lecturer in zooarchaeology at the Institute of Archaeology, University of London in 1974. It was during this period that his interest extended from human remains to animal bones, including the archaeology of animal disease. This was the time when, inspired by so-called New Archaeology, the application of scientific methods was emerging in archaeology world-wide. In 1974, Brothwell founded the influential *Journal*

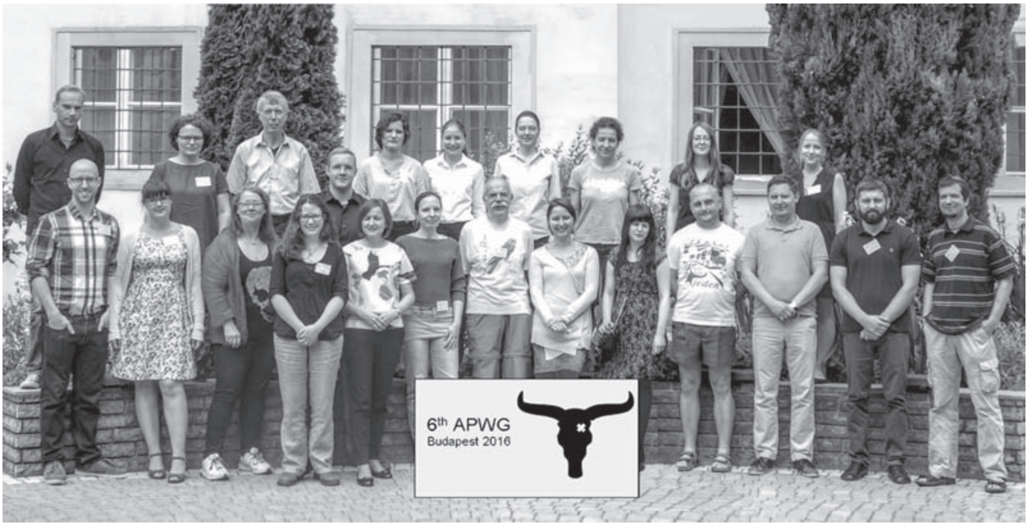
Left: Sándor Bökönyi in the 1980s lecturing at the Eötvös Loránd University in Budapest, Hungary; Right: Don Brothwell in 2010 during the fourth Animal Palaeopathology Working Group Conference in Katerini, Greece.

of Archaeological Science. Among archaeozoologists, however, he will probably remain best known as co-author with John Baker of the first modern book on the archaeological applications of animal palaeopathology: *Animal Diseases in Archaeology* (1980). Prior to that publication, the topic had been usually studied by palaeontologists and lacked any cultural perspective.

The 2016 APWG conference was one of the last international meetings organised at the Institute of Archaeology, Research Centre for the Humanities, Hungarian Academy of Sciences prior to its re-location in a former industrial zone from the historic building complex in the prestigious Buda Castle District. The venue of the APWG meeting once served as the refectory of a Franciscan monastery built during the early 18th century in Baroque style. At the end of 1794, Hungarian noble revolutionaries called Jacobins were tried in this room, hence its name, "Jacobin Hall".

The 25 participants attending the conference represented twelve countries from three continents. Their research, illustrated by contributions to this volume, encompasses a dozen countries in Eurasia. Remarkably, the overwhelming majority of participants were early-career scholars, a promising trend in furthering the legacy of previous generations of archaeozoologists devoted to promoting the study of animal disease in the past.

In order to guarantee the high academic standards of this volume, contributors – all experts in the field – were asked to peer-review each other's manuscripts. In addition, however, several colleagues served as external reviewers to help improve



Participants of the sixth meeting of the Animal Palaeopathology Working Group in Budapest (Photo: Melinda Vindus).

the manuscripts both in terms of contents and linguistic clarity. We would also like to take this opportunity to thank John Chapman, Alice M. Choyke, Damien Huffer, Eve Rannamäe, William Taylor and Eric Tourigny for their enthusiastic support during the preparation of manuscripts.

The editors

List of Contributors

Annamária Bárány
Hungarian National Museum
1088 Budapest, Múzeum körút 14–16, Hungary
annambarany@gmail.com

Henriette Baron
Römisch-Germanisches Zentralmuseum
Leibniz-Forschungsinstitut für Archäologie
Ernst-Ludwig-Platz 2, D-55116 Mainz, Germany
baron@rgzm.de

László Bartosiewicz
Osteoarchaeological Research Laboratory
Stockholm University
Lilla Frescativägen 7, 106 91 Stockholm, Sweden
laszlo.bartosiewicz@ofl.su.se

Lauren Bellis
School of Archaeology and Ancient History
University of Leicester
University Road, Leicester, LE1 7RH, United Kingdom
lb342@le.ac.uk

Anna Zsófia Biller
Aquincum Museum
1031 Budapest, Szentendrei út 135
biller.anna@aquincum.hu

Aleksander Chrószcz
Department of Biostructure and Animal Physiology
Wrocław University of Environmental and Life Sciences
Kozuchowska 1/3, 51-631 Wrocław
Poland
bjorn@onet.pl

Pamela J. Cross
University of Bradford, Archaeological Sciences
Richmond Road, Bradford BD7 1DP, United Kingdom
p.j.cross@student.bradford.ac.uk

László Daróczi-Szabó
Independent zooarchaeologist
1144 Budapest, Újváros park 4–5, Hungary
lacidsz@freemail.hu

Márta Daróczi-Szabó
Independent zooarchaeologist
1144 Budapest, Újváros park 4–5, Hungary
martidsz@gmail.com

Yves Darton
Université Côte d'Azur, CNRS, CEPAM
24 Avenue des Diables-Bleus, 06357 Nice Cedex 4 France
yves.darton@cepam.cnrs.fr

Erika Gál
Institute of Archaeology, Research Centre for the Humanities
Hungarian Academy of Sciences
1097 Budapest, Tóth Kálmán utca 4, Hungary
gal.erika@btk.mta.hu

Jennifer Harland
Archaeology Institute, University of the Highlands and Islands
East Road, Kirkwall, Orkney, KW15 1LX, UK
Jen.Harland@uhi.ac.uk

Yasha Hourani
Independent zooarchaeologist,
Urban Excavations of the Directorate General of Antiquities,
Mathaf Main Road, Beirut, Lebanon
yashahourani@hotmail.com

Vujadin Ivanišević
Institute of Archaeology
Kneza Mihaila 34/IV, 11000, Belgrade, Serbia
vujadin.ivanisevic@gmail.com

Maciej Janeczek
Department of Biostructure and Animal Physiology
Wrocław University of Environmental and Life Sciences
Kozuchowska 1/3, 51-631 Wrocław
Poland
maciej.janeczek@up.wroc.pl

Hanna Kivikero
Department of philosophy, history, culture and art studies,
University of Helsinki
Archaeology PB 59, 00014 Helsinki, Finland
hanna.kivikero@helsinki.fi

Günther Karl Kunst
Vienna Institute for Archaeological Science
University of Vienna
Althanstrasse 14, A-1090 Vienna, Austria
guenther.karl.kunst@univie.ac.at

Nikola Krstić
Faculty of Veterinary Medicine, University of Belgrade
Bulevar Oslobođenja 18, 11000, Belgrade
Serbia
dr.nikola.kr@gmail.com

Kyra Lyublyanovics
Department of Medieval Studies
Central European University
1051 Budapest, Nádor utca, Hungary
lyublyanovicsk@ceu.edu

Darko Marinković
Faculty of Veterinary Medicine, University of Belgrade
Bulevar Oslobođenja 18, 11000, Belgrade
Serbia
darko@vet.bg.ac.rs

Nemanja Marković
Institute of Archaeology
Kneza Mihaila 34/IV, 11000, Belgrade
Serbia
nemamarkovic@gmail.com

Éva Ágnes Nyerges
Institute of Archaeology, Research Centre for the Humanities
Hungarian Academy of Sciences,
1097 Budapest, Tóth Kálmán utca 4
nyerges.evaagnes@btk.mta.hu

Kamilla Pawłowska
Institute of Geology, Adam Mickiewicz University
ulica Krygowskiego 12, 61-680 Poznań, Poland
koka@amu.edu.pl

Isabelle Rodet-Belarbi
Inrap, Université Côte d'Azur, CNRS, CEPAM
24 Avenue des Diables-Bleus, 06357 Nice Cedex 4 France
isabelle.rodet-belarbi@inrap.fr

Oliver Stevanović
PI Veterinary Institute of Republic Srpska "Dr.VasoButozan"
Branka Radičevića 18, 78000 Banja Luka
Bosnia and Herzegovina
oliver.13.stevanovic.bih@gmail.com

William Taylor
Max Planck Institute for the Science of Human History
Kahlaische Strasse 10, 07745 Jena, Germany
taylor@shh.mpg.de

Tumurbaatar Tuvshinjargal
National Museum of Mongolia
1 Tourist Street, Ulaanbaatar, 210146, Mongolia
ttuvshinjargal01@gmail.com

Wim Van Neer
Royal Belgian Institute of Natural Sciences
Vautierstraat 29, B-1000 Brussels, Belgium; and
Laboratory of Biodiversity and Evolutionary Genomics
University of Leuven, B-3000 Leuven, Belgium
wvanneer@naturalsciences.be

1. Introduction: Care, Neglect and the "Osteological Paradox"

László Bartosiewicz and Erika Gál

A review article on prehistoric human and animal bone injuries by Gérard Cordier (1990) illustrated that pathological lesions on animal remains during the 19th century were usually recorded with a focus on prey animals that had survived previous violent encounters with human hunters, as attested by healed wounds. In fact, the term palaeopathology was first defined in relation to an assemblage of early prehistoric bird remains and associated lithic artefacts as a study of "all diseased or pathological conditions found fossilised in the remains of extinct or fossil animals" (Shufeldt 1893, 679).

With the onset of domestication animal–human relations diversified. Human contact with animals was no longer limited to killing game. Domestication impacted on heritability through reducing pressures of natural selection in isolated herds. The diets and habitats of such animals were limited or even changed. Domestication also created new arenas of interaction between animals and humans which not only increased the risks of mutually infectious diseases (zoonoses), but also opened new avenues for potential conflict. Last but not least, the exploitation of domesticates has been a constant source of additional stress, frequently leaving marks on the animal skeleton.

Health aspects of animal domestication seem to have followed a trajectory similar to that of the key transition of human society from hunting and gathering to sedentary agriculture. During the latter process, palaeopathological evidence was "equally consistent with an improvement in health and a deterioration in health resulting from the transition" (Wood *et al*. 1992, 343). This sentence expresses the essence of what became known as the "osteological paradox" in palaeopathology. The title of our volume is a reference to this concept.

In spite of the fundamental differences between the anatomical structure and taphonomy of excavated animal and human remains, the osteological paradox is equally relevant to animal palaeopathology. Lesions of bone take time to both develop and heal. Consequently, individuals displaying such skeletal changes must have lived a long time with the underlying condition. Osteological symptoms, then, could rather be seen as evidence of fitness, *i.e.* the individual having successfully survived a disease, rather than that the individual being atypically weak and sickly. Trying to appraise whether bone deformations were caused by poor keeping conditions or even cruelty, in contrast to special care accorded to suffering individuals or pampered pets (Udrescu and Van Neer 2005) has been instrumental in understanding subtleties in past animal–human relationships, a key feature in any culture.

Some animal remains, usually those of domesticates, can show signs of debilitating conditions. Manifestations of disease vary highly, both between animal species and time periods. Behind these phenomena lie ever-changing perceptions of animals, both healthy and diseased (Thomas 2005). Human predation on animals (including domesticates) is clearly illustrated by evidence of food refuse from archaeological sites. Special structured deposits such as joint human–animal burials may be more indicative of an affectionate attitude, but they also attest to the probably ritual killing of the animal. The role of animals as companion, even through the eternal journey, can be far more reliably reconstructed from iconographic or documentary sources of evidence than osteoarchaeological data (Bartosiewicz 2011).

The structure of this volume presents examples of various research situations in animal palaeopathology. The introductory site reports follow a diachronic order. They illustrate the scarcity of information on animal disease gleaned from fragmented commingled refuse bone assemblages originating from even large archaeological settlements (Chapters 2–5). They represent, however, the inevitable first step toward the long-term relevance of our field of research. Viable sample sizes are indispensable in the realistic assessment of animal disease in the past. But they do not come easy.

Turning from scattered remains of ordinary livestock to "man's best friend", dog burials can provide clearer insights into animal–human relations from a osteoarchaeological perspective, thanks to the anatomical integrity of articulated skeletons (Chapters 6–8). Similar deposits of horses usually reconfirm the special position of these beasts across archaeological epochs, even if their treatments have varied radically between cultures (Chapters 8–12). Among birds, domestic chickens may be seen as special from a palaeopathological point of view, since series of their articulated skeletons may also be recovered from burials (Chapter 13).

Aside from such "privileged" animals, many domesticates show curious skeletal anomalies resulting from inadvertent or conscious artificial selection (Chapters 14, 16) or consequences of documentable brutal treatment (Chapter 15). Pathological lesions are relatively rarely identified on the bones of wild animals, mentioned only in passing in some chapters of this book. However, the last two chapters (Chapters 17 and 18), devoted to palaeopathological lesions on fish bones from archaeological sites, open encouraging new vistas in this previously unexplored area of research.

Recently animal studies have begun attracting increasing attention among those who investigate the human past: archaeologists and historians. In part, this success is attributable to the fact that scientific information offered by animal remains from archaeological sites has reached a critical mass, beyond which it can be more easily integrated into historical narratives than individual site reports on animal finds. The evaluation of pathologically modified animal remains is also benefitting from this trend. Synthesised into sophisticated theoretical models, such analyses gain a new quality in answering broader questions regarding ancient societies (*e.g.* Fournié *et al.* 2017). Contributions to this volume represent several stages of this scholarly process, illustrating the abundance of information inherent in rare pathological specimens painstakingly retrieved from excavated animal bone assemblages.

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2. Animal Diseases in Neolithic Societies: Çatalhöyük (Turkey) in the Spotlight

Kamilla Pawłowska

Not all disease entities leave marks on bones, and there are thus certain limitations in recognising animal diseases through the examination of zooarch aeological assemblages. However, a systematic review of pathology records, here provided on the example of Çatalhöyük East in Turkey, allows light to be shed on issues of animal husbandry and management from the early Neolithic onwards.

This paper is focused on the interpretative potential of the various kinds of observed pathologies that affect animal bones in regards to issues of domestication, feeding conditions, and the means of keeping animals in a Neolithic society. Attention is also paid to congenital and developmental defects, as well as to age-related degenerative diseases.

The results revealed more pathological occurrences on the earlier levels than on the later levels in the Neolithic sequence and the post-Neolithic contexts, although the presence of animal pathologies is generally low. The study shows that inflammatory diseases, dental anomalies, and oral pathology predominate over arthropathies, congenital anomalies, traumatic lesions, and diseases associated with the environment in the assemblages as a whole. This concerns various species; however, cases of pathology are particularly prevalent in caprines, which, along with cattle, played a major role in subsistence strategies at Çatalhöyük.

2.1 Introduction

Çatalhöyük (37°39′58″ N, 32°49′38″ E) is an archaeological site located in central Anatolia in Turkey, and is well known in the Near East due to its large size, complex structure, and its contributions to our understanding of many aspects of daily life in the past.

The excavation focusing on the East Mound has revealed the presence of many occupational levels (Mellaart levels: XII–0; Hodder levels: South.G–South.T, 4040.F–4040.J, TP.M–TP.R). The Neolithic sequence covers period from 7100 to 5900 cal BC (see, for example, Bayliss *et al*. 2015, Hodder 2013).

Animal palaeopathology is concerned with those skeletal alternations that result from disease processes, traumatic insults, nutritional dysfunction, metabolic imbalance, developmental disruptions, and lifestyle (Thomas and Miklíková 2008). Among the faunal remains that have been studied so far at Çatalhöyük, some display pathological phenomena that are the main focus in this paper. Although there are certain limitations in recognising animal diseases through the examination of zooarchaeological assemblages,

since not all disease entities leave marks on bones, such assemblages can be used to shed light on the physical condition of animals. This issue is crucial in the light of animal domestication, and at Çatalhöyük, it is known that both sheep and cattle were domesticated (Pawłowska in press, Russell *et al*. 2013); this material therefore provides an opportunity to study the health and disease of domesticated livestock from very early domestication onwards.

2.2 Materials and methods

The materials used in this synthesis are derived mainly from the Neolithic, but also from later periods, here referred to as post-Neolithic. Because the precise chronology of the post-Neolithic is not yet known, this broad term is used here.

The samples are derived from various occupational levels, and from recently obtained analyses and published sources (Pawłowska in press, Russell and Martin 2005, Russell 2012, Russell *et al*. 2013). Previous publications have dealt with specimens from Neolithic levels in the occupational sequence, while many of the Late Neolithic and post-Neolithic samples are presented here for the first time. Context types include middens, fills, special deposits and floor deposits. This work is not intended to show any relation between the observed pathology issues and the various contexts of the finds.

In total, a sample of 232 faunal remains from the Neolithic assemblages and 59 from the post-Neolithic assemblages were included in this study. They were chosen on the basis of reliable stratigraphic records and the well-known context. They comprise a negligible proportion (less than 0.1%) of the total faunal remains analysed (more than one million). These represent 222 pathological occurrences in total (Table 2.1). It is worth emphasising that all originate from secure contexts.

The analysis of pathology was conducted using a wide range of references (*e.g*. Baker and Brothwell 1980; Bartosiewicz and Gál 2013). From the various techniques that could be used to study pathological specimens (*e.g*. histological and radiographic methods) macro-morphological analysis was used here, since all the material was studied only in the lab on site without access to the specialised equipment needed for other techniques. The analysis was carried out using a magnifying glass (×30).

The term "caprines" is used here to refer to sheep and goats; these taxa are combined into one category when it was not possible to precisely identify the species.

All specimens are stored at the Çatalhöyük depots, and detailed data (including contextual information) is available from the Çatalhöyük database.

2.3 Results and discussion

From the Çatalhöyük assemblages, 222 pathological occurrences were noted in 291 specimens (Table 2.1). These came mostly from the earlier levels (79%) and, to a lesser extent, from later levels (16%) and post-Neolithic contexts (5%). Of the latter, the difference

Table 2.1. Çatalhöyük East: Sample of pathological cases used in this study.

	NISP	*Pathological cases*
Neolithic (early levels)	197	176
Late Neolithic	35	35
Post-Neolithic	59	11
Total	291	222

between the number of identified specimens and the number of pathological phenomena is mainly due to the presence of a dog skeleton, elements of which show evidence of osteomyelitis, arthropathy, and fracture. For the Neolithic context, the difference in question is associated with finds of bones in articulation, which were counted as one pathological phenomenon within the skeleton of one animal.

Generally, inflammatory diseases (25%), dental anomalies, and oral pathology (22%) predominate over arthropathies (13%), congenital anomalies (5%), traumatic lesions (3%), and diseases associated with the environment (4%) in the Neolithic assemblages (Figure 2.1, Table 2.2). This is also seen in the assemblages as a whole (Table 2.2). There are also other pathologically modified bones (28%) with exostoses as the dominant indications of lesions. These are presented next.

2.3.1 Inflammatory diseases and bone

Inflammatory conditions of bone are the most common pathological lesions at Çatalhöyük (Figure 2.1, Table 2.2). This is consistent with the statement of Baker and

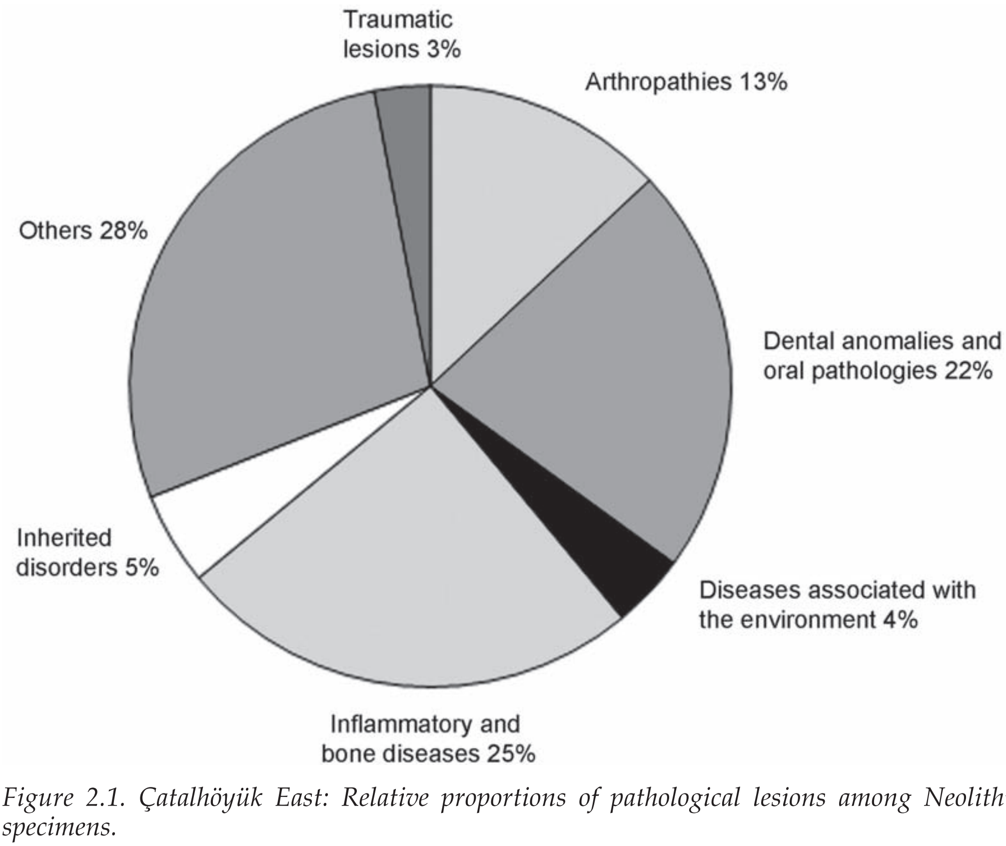

Figure 2.1. Çatalhöyük East: Relative proportions of pathological lesions among Neolithic specimens.

Brothwell (1980) that such conditions are common in excavated bones. Osteomyelitis and periosteitis (distinguished by the location of inflammation origin, Bartosiewicz and Gál 2013), abscesses, and other symptoms of infection or inflammation were found among the Çatalhöyük assemblages (Table 2.3).

Analysis of Neolithic contexts indicated that symptoms of abscesses predominated (almost half), along with osteomyelitis (one-quarter) and periosteitis (less than one-tenth), aside from those with evidence of other inflammatory responses (one-quarter).

Abscesses, which are accumulations of pus or other exudates (Bartosiewicz and Gál 2013), were mostly seen in caprine specimens, though a certain number were also

Table 2.2. Çatalhöyük East: Chronological distribution of pathological lesions.

	Neolithic (early levels)	*Late Neolithic*	*Total*	*% of Neolithic*	*Post-Neolithic*	*Total*	*% of Total*
Arthropathies	25	2	27	13	1	28	13
Dental anomalies and oral pathology	37	9	46	22	3	49	22
Diseases associated with the environment	6	2	8	4		8	4
Inflammatory and bone diseases	41	12	53	25	1	54	24
Inherited disorders	6	5	11	5	1	12	5
Traumatic lesions	6		6	3	2	8	4
Other	55	5	60	28	3	63	28
Total	176	35	211	100	11	222	100

Table 2.3. Çatalhöyük East: Taxonomic distribution of inflammatory diseases.

	Sheep	*Goat*	*Caprine*	*Sheep-size*	*Cattle*	*Cattle-size*	*Equid*	*Dog*	*Boar*	*Total*
Neolithic (early levels)	6	1	23		5	1	2	1	2	41
Abscess	2		14		3		1		2	22
Osteomyelitis	3	1	6					1		11
Other	1		3		2	1	1			8
Late Neolithic	3		4	2		3				12
Osteomyelitis			1	2						3
Periosteitis	1		2			1				4
Other	2		1			2				5
Post-Neolithic								1		1
Osteomyelitis								1		1
Total	9	1	27	2	5	4	2	2	2	54

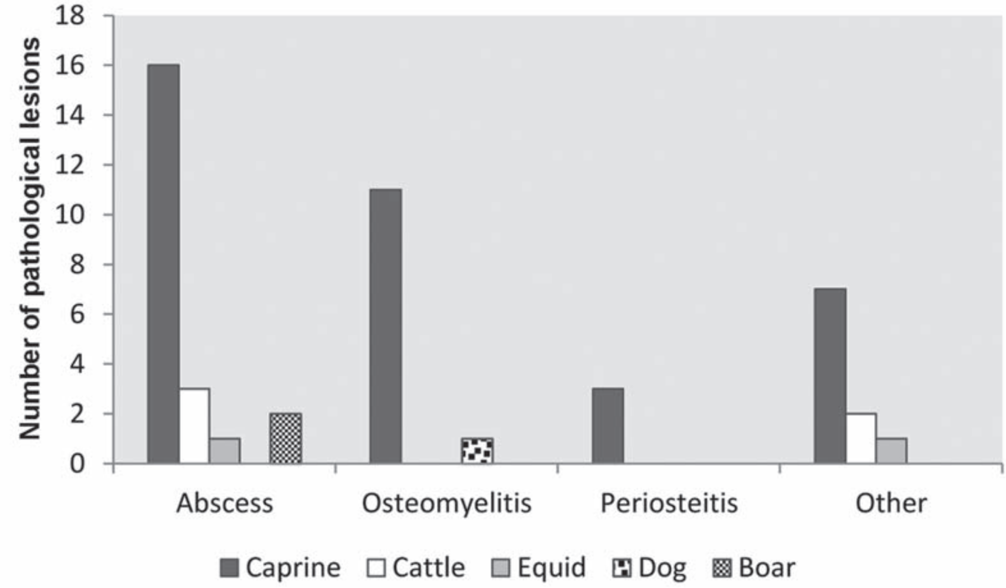

Figure 2.2. Çatalhöyük East: Frequency and taxonomic distribution of inflammatory diseases among Neolithic specimens.

present among cattle, equids, and boars (Figure 2.2). Abscesses are mostly associated with the mandibles, being located near P_4 and M_3 teeth, although they are also seen on maxillae, teeth, a scapula, and a metapodial (Tables 2.4, 2.5). Abscesses may have serious effects, especially when they develop into fistulae, but at least some of the Çatalhöyük mandibles show evidence of healed abscess (Table 2.5). The presence of a drainage hole in four cases (Table 2.5) is indicative of long-standing abscess according to Baker and Brothwell (1980), which is also supported by alveolar loss in some of them. The development of abscesses is, in at least some cases, interpreted as a likely result of heavy tooth wear or of injuries that developed into this kind of lesion (Russell and Martin 2005; Russell *et al*. 2013).

The second most important anomaly reported at Çatalhöyük is osteomyelitis: inflammation of bone beginning in marrow cavities (Baker and Brothwell 1980), seen here on various caprine limb elements and on the lumbar vertebrae of sheep-size bones (TPC Area, Team Poznan Connection) and dog bones (Figure 2.2, Table 2.4). In some pathological specimens, the osteomyelitis probably originated from an injury, as is the case with caprine second and third phalanges and metatarsal (Russell *et al*. 2013).

In the case of the dog specimen, signs of osteomyelitis are present on the transverse processes of two lumbar vertebrae, which were broken off in life near the base; one remained with the skeleton, most likely as a consequence of a blow to the lower back. Infection could begin through the skin at the location of the fracture (Russell *et al*. 2013).

Table 2.4. Çatalhöyük East: Taxonomic and skeletal distribution of cases of abscess and osteomyelitis (Neolithic specimens).

	Sheep	*Goat*	*Caprine*	*Sheep-size*	*Cattle*	*Equid*	*Dog*	*Boar*	*Total*
Abscess	2		14		3	1		2	22
Mandible	2		9		2			1	14
Maxilla								1	1
Metapodial			1						1
Scapula					1				1
Teeth (mandibular)			2			1			3
Teeth (maxillary)			2						2
Osteomyelitis	3	1	7	2			1		14
Femur			1						1
Humerus			2						2
Metacarpus		1							1
Metatarsus	1		1						2
Phalanx	2		2						4
Radius			1						1
Vertebra (lumbar)				2			1		3
Total	5	1	21	2	3	1	1	2	36

Table 2.5. Çatalhöyük East: Location of abscesses in animal mandibles. A single entry corresponds to a single specimen. Asterisks indicate the presence of the drainage hole in specimens; boldface print indicates cases of healed abscesses (Neolithic specimens).

Location	*Sheep*	*Caprine*	*Cattle*	*Boar*
Diastema		**diastema**		
Premolars and M1	**M1**	dp3 and M1 *		**M1**
		P4		
		P4 *		
		between P4 and M1		
M2 & M3		M3	ascending ramus and roots of M3	
		M3 *		
		M2 and M3 *		
Horizontal ramus and heel area	**horizontal ramus below M3**	**horizontal ramus**	heel area	
Total	2	9	2	1

Periosteitis, in contrast to osteomyelitis, starts in the periosteum (Baker and Brothwell 1980); it is not common among the Çatalhöyük samples, and where it does occur, it is found among caprine single elements of mandibles, femurs, and an astragalus from the TPC Area in the new project (Figure 2.2).

Other lesions include cases of infection that mainly result from injury (Figure 2.2). Among these are signs of healing processes, as in the case of the sheep, cattle, and equid bones (Russell 2012; Russell and Martin 2005; Russell *et al*. 2013).

Comparing pathological lesions in the Çatalhöyük sequence, the complete lack of evidence of abscesses in the Late Neolithic levels is noticeable. This could be related either to better health conditions among the animals (especially the caprines) with regard to infections that cause inflammation, or it could be a function of the smaller sample.

Osteomyelitis was the main pathological lesion on a dog skeleton (post-Neolithic) that also displayed signs of traumatic lesions and an arthropathy. Osteomyelitis is present on the forelimbs (radius and ulna), as well as on a thoracic vertebra, ribs, and a first phalanx.

2.3.2 Dental anomalies and oral pathology

Teeth can reflect both systemic effects inherent to the animal's body, such and growth and non-specific stress, as well as direct external influences in the form of tooth wear and infections caused by the variety of microbes that inhabit the oral cavity (Bartosiewicz and Gál 2013, 171).

Dental anomalies are the formative defects caused by genetic disturbances or environmental factors during tooth morphogenesis (Nagaveni 2012). Those associated with potential genetic factors are discussed separately later.

Irregularities in tooth wear are more frequent than periodontal disease, calculus, or caries among the pathological specimens from Çatalhöyük (Table 2.6). Caries, which results from continuous damage to teeth by plaque-forming bacteria (Bartosiewicz and Gál 2013), is only known from a single case of a goat deciduous third premolar in the earlier Neolithic levels (Russell and Martin 2005) (Figure 2.3). Calculus, consisting of concretions formed by dental plaque, was recently found in the TPC Area material (Late-Neolithic) on caprine teeth of maxillae (upper row in Figure 2.4) and mandibles (Figure 2.3). Among these, the deformation of the tooth row, in the form of a curved P^2, is also evident.

Among the Neolithic specimens, irregularities in tooth wear (41%) and periodontal disease (33%) are more evident than calculus, caries, or other dental anomalies.

Irregularities in tooth wear are more associated with mandibles and isolated upper and lower teeth of sheep and goat, compared to cattle, equids, or foxes (Figure 2.3, Table 2.7). Malocclusion, the mismatching of the upper and lower rows of teeth (Bartosiewicz and Gál 2013), is most common in this regard, and is usually observed as a pattern of tooth wear differing between the anterior and posterior cusps. It is interpreted as the result of injury (n=2), abscess (n=1), or the loss of upper teeth, including one case of each of P^2, M^1, and M^2 (Pawłowska in press; Russell and Martin 2005; Russell *et al*. 2013). The specimen with the injury was a fox mandible with extremely heavy, anomalous wear on the first molar, in contrast to the third

Table 2.6. Çatalhöyük East: Taxonomic distribution of dental anomalies and oral pathology.

	Sheep	*Goat*	*Caprine*	*Cattle*	*Equid*	*Cervid*	*Dog*	*Fox*	*Badger*	*Total*
Neolithic (early levels)	7	4	14	7	1	1		2	1	37
Caries		1								1
Irregularities in tooth wear	3	3	6	2	1			1		16
Irregularities in tooth wear & abscess	2									2
Periodontal disease	2		3	3		1				9
Other			5	2				1	1	9
Late Neolithic			8	1						9
Calculus			2							2
Irregularities in tooth wear				1						1
Periodontal disease			2							2
Other			4							4
Post-Neolithic		1	1				1			3
Irregularities in tooth wear		1	1							2
Other							1			1
Total	7	5	23	8	1	1	1	2	1	49

premolar, which is not especially worn. It seems likely that the tooth was broken and subsequently worn down (Russell and Martin 2005). Abscesses as a cause of malocclusion are indicated by distortions of caprine lower P_4 roots, aside from excessive mesial wear (Russell and Martin 2005). Moreover, two sheep mandibles from senile individuals show the presence of abscesses and anomalous wear (P_4–M_1 and M_1–M_3 areas, respectively), perhaps indicating a more general infection, at least in this mandible, where severe abscesses at the second and third molars led to their loss in life (Russell *et al*. 2013; Table 2.6). Also observed was the concave pattern of an M_1 in a sheep mandible, as a consequence of being much more deeply worn than the surrounding teeth (Russell *et al*. 2013).

Isolated caprine teeth show anomalous wear, in one case indicating poor occlusion; in another, small pits or voids in the dentine additionally occur (Table 2.7).

Two cases of indentation of the tooth neck are related to nutrition, though there are some differences between them (Table 2.7). As reported by Russell *et al*. (2013), two cattle deciduous incisors, probably articulated, with deep notches, are the result of pulling grass through the teeth. Grooving and polishing of the root at the base of the crown of cattle mandibular tooth (premolar or molar) could be from trapped grass, as shown by the results of recent research (Late Neolithic; TPC Area).

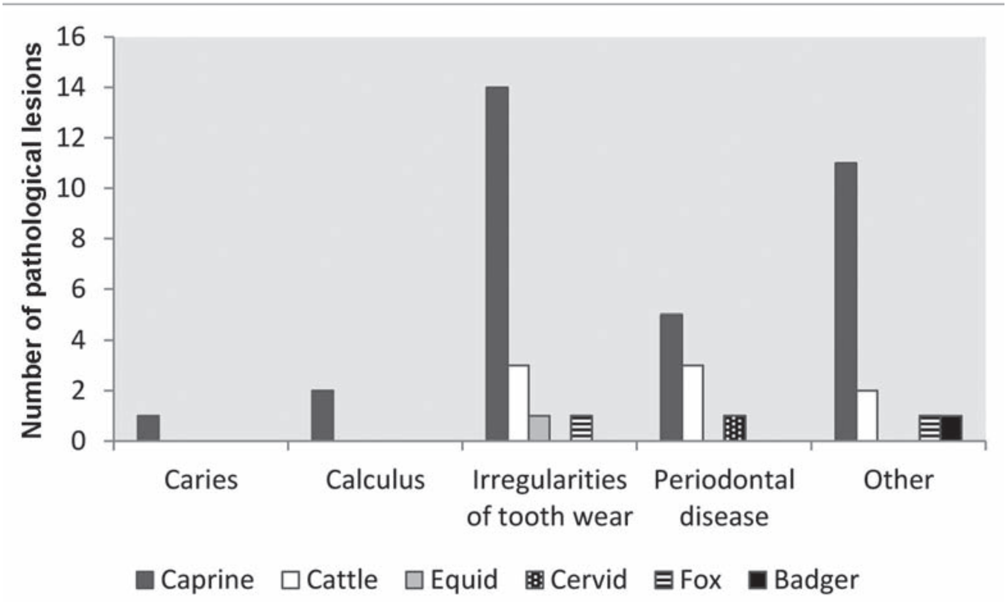

Figure 2.3. Çatalhöyük East: Frequency and taxonomic distribution of dental anomalies and oral pathology among Neolithic specimens.

One more irregularity of tooth wear is observed on an equid tooth in the form of a deep notch along the crown–root junction on the buccal side, with evidence of secondary dentine beginning to cover the edges (Russell *et al*. 2013; Table 2.7).

Periodontal disease, which mainly derives from localised bacterial infections that turn chronic, and is attributable to injury of the gums caused by food (Bartosiewicz and Gál 2013 with further references), is recognised in caprine, cattle, and cervid specimens (Figure 2.3, Table 2.6). It is visible as an alveolar recession or loss from sheep and caprine mandibles, and also as inflammation resulting from a foreign object becoming lodged in the alveolus, which can be seen as an irregular pocket in the enamel, below the gum line, with a shallow trough leading from it to the occlusal surface (Russell and Martin 2005; Russell *et al*. 2013). This evokes a case recognised by Colyer (1936, in Bartosiewicz and Gál 2013) as an injury of a chemical nature, where the products of rotting food injured the epithelial surface and exposed the deeper tissues to infection.

Hypercementosis, which refers to the excessive formation of cementum beyond the extent necessary to fulfill its normal functions, results in abnormal thickening with macroscopic changes in the tooth root (Consolaro *et al*. 2012). This constitutes another pathological condition, only observed along the root of one isolated and heavily worn lower first molar from a caprine (Russell *et al*. 2013). Hypercementosis is not uncommon among caprines, and taken as indicative of the overuse of infected pastures, crowded conditions, or both (Grigson 1987, in Bartosiewicz and Gál 2013); it may also be associated with older animals (Baker and Brothwell 1980).

Periodontal disease is seen in cattle in the case of three mandibles, where it is associated with excessive wear on the P_4 and M_1, causing observed alveolar loss (in a senile animal) and crowding of teeth (P_2 and P_3). It is associated with the part rotation of the M_1, which provoked periodontal disease between the first and second molars (Russell *et al*. 2013).

The alveoli of all of the premolars in a cervid mandible are distorted and spongy and do not retain these teeth; it has been suggested that this derives from extreme wear, and is also an age-related lesion, as it comes from a very old animal (Russell and Martin 2005).

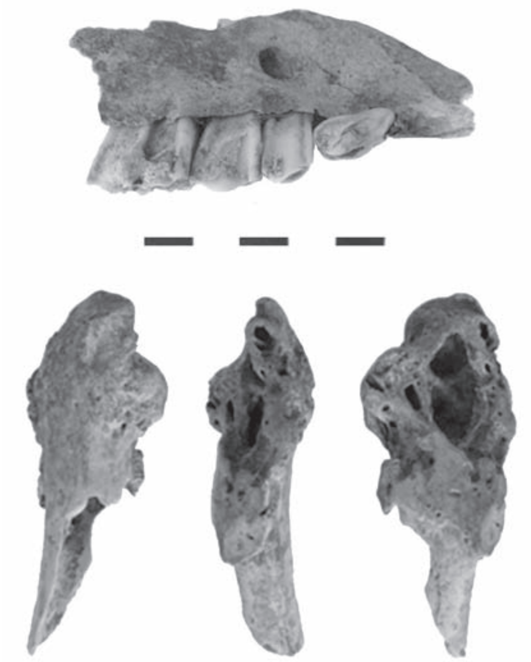

Figure 2.4. Caprine maxilla displaying extent of calculus and P2 anomaly (upper row) and presumably a femur of bird showing disease of the hip joint (lower row) (Photo: K. Pawłowska).

Among the post-Neolithic assemblage, irregularities in tooth wear are only seen among goat, caprine, and dog specimens, aside from the dental anomalies already noted in the Neolithic Çatalhöyük sequence. In the caprine upper tooth from TP.S level, this is expressed as extremely atypical wear in the form of heavy interstitial wear and occlusal wear slopes down to the buccal margin, rather than down toward the lingual margin. In the second specimen, goat mandibles have anomalous wear on dp_2 and dp_3 (TP.W level). The posterior cusp of dp_2 and the anterior and posterior cusps of dp_3 seem unusually worn, while the middle cusp of the dp_3 forms a high peak. The pattern seems to be caused by a damaged tooth. The dog mandible (TP.U level) displays abnormalities of the P_4 in the form of partly formed enamel, which might indicate that it either did not form properly, or else was being resorbed. As a result, it failed to erupt.

2.3.3 Arthropathies

Diseases of joints are common abnormalities of animal skeletons in archaeological material (Baker and Brothwell 1980). Among the Çatalhöyük assemblages, they are less numerous than inflammatory diseases, dental anomalies, and oral pathology; they are nonetheless quite common, being the third most significant group (Figure 2.1).

Osteoarthritis is a degenerative disease primarily affecting the articular cartilage (Baker and Brothwell 1980), and is the most common pathology of the joints in the

Table 2.7. Çatalhöyük East: Taxonomic and skeletal distribution of cases of irregularities in tooth wear (Neolithic specimens).

	Sheep	*Goat*	*Caprine*	*Cattle*	*Equid*	*Fox*	*Total*
Malocclusion	3	3	4	1		1	12
mandible	1	1	1	1		1	5
P2 mand.			1				1
P3 mand.			1				1
P4 mand.	1		1				2
M3 mand.	1	2					3
Anomalous wear			2				2
P max.			1				1
M3 max.			1				1
Indentation of neck of tooth				2			2
Id 2/3 mand.				1			1
P/M mand.				1			1
Other					1		1
P/M mand.					1		1
Total	3	3	6	3	1	1	17

assemblages from the earlier Neolithic levels, being observed in caprines, sheep, goat, cattle, and equid specimens (Figure 2.5, Table 2.8). Although Baker and Brothwell (1980) pointed out that at least three out of four alternations – such as grooving, eburnation, extension of the articular surface, and exostoses – should be found in order to diagnose osteoarthritis, cases of incipient osteoarthritis (Russell *et al*. 2013), in which only two features were observed, are also included here.

Five other pathological phenomena are associated with advanced exostoses causing bone fusion (ankylosis), making up 30% of the specimens with evidence of arthropathies (Figure 2.5, Table 2.9). In three cases, a disease of the tarsus led to chronic fusion of the tarsal bones (spavin) or of tarsals to the metatarsus. This condition is a result of a primary dry tarsal joint inflammation (Bartosiewicz and Gál 2013), and in the case with the fused metatarsal, a general stress on the joint or an injury seems to have been involved (Russell 2012). It is not possible to precisely determine the cause of every lesion, such as exostosis on other caprine carpal bones (n=2) and the tarsal bone (n=1), though these may also be age-related.

There is also evidence of ring bone (11%) from severe exostosis of sheep and goat second phalanges (Russell *et al*. 2013). The cause of ring bone formations include concussion, old age, and overstrain on interphalangeal joints (Baker and Brothwell 1980; Driesch 1975, in Bartosiewicz and Gál 2013). The condition can lead to physical discomfort – as Baker and Brothwell (1980) claim, ring bone nearly always causes a greater or lesser degree of lameness.

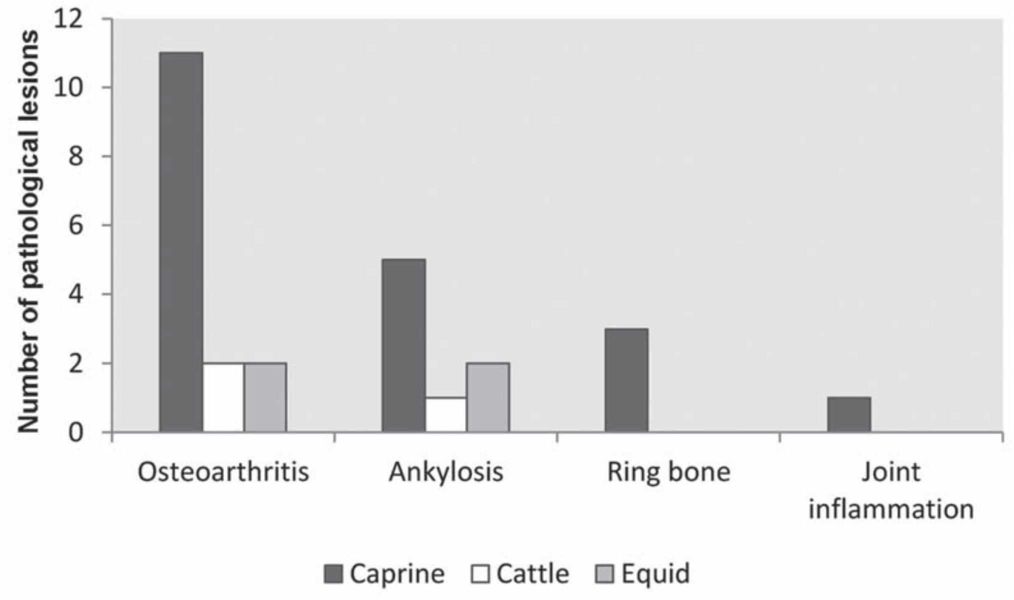

Figure 2.5. Çatalhöyük East: Frequency and taxonomic distribution of arthropathies among Neolithic specimens.

Table 2.8. Çatalhöyük East: Taxonomic and skeletal distribution of osteoarthritis.

	Sheep	*Goat*	*Caprine*	*Cattle*	*Equid*	*Total*
Neolithic (early levels)	3	2	5	2	2	14
Humerus	3		1			4
Pelvis				2	1	3
Phalanx		1				1
Radius		1				1
Radius and Ulna			1			1
Tarsal					1	1
Ulna			2			2
Vertebra (cervical)			1			1
Late Neolithic			1			1
Radius			1			1
Total	3	2	6	2	2	15

In the Late-Neolithic assemblages, individual cases of osteoarthritis and general joint inflammation can be seen (Figure 2.5; TPC Area), for example in the bird bone distorted by disease of the hip joint (lower row in Figure 2.4; TPC Area).

Table 2.9. Çatalhöyük East: Taxonomic and skeletal distribution of ankyloses. Asterisks indicate the presence of spavin.

	Goat	*Caprine*	*Cattle*	*Equid*	*Total*
Neolithic (early levels)	1	1	1	2	5
Second and third carpal				1	1
Metatarsus and tarsals			1*		1
Central and third tarsal				1*	1
Second, third tarsal is fused to the central and fourth tarsal		1*			1
Tibia and malleolus	1				1
Post-Neolithic			1		1
Central tarsal			1		1
Total	1	1	2	2	6

For the post-Neolithic specimens, the fusing of cattle second and third tarsals with the central tarsal is indicative of spavin.

2.3.4 Inherited disorders

Although a congenital disease is not always passed on, all observed congenital anomalies are classified as inherited disorders, according to Bartosiewicz and Gál (2013). A congenital anomaly refers to one that was present at birth. Caprine, sheep, and cattle elements display such lesions in the Çatalhöyük assemblages (Table 2.10).

Among these pathological phenomena, half of the specimens from earlier Neolithic levels (n=3) represent dental anomalies in the form of oligodonty – a reduction in the number of teeth (Bartosiewicz and Gál 2013). This can be seen in the case of sheep and caprine mandibles where, as noted by Russell *et al*. (2013) and by Russell and Martin (2005), there are no second permanent premolars. This kind of a subpathological anomaly is quite well known in archaeology, and is recognised in both wild and domestic animals including aurochs, mustelids, badgers, foxes, caprines, cattle, and pigs (Bartosiewicz and Gál 2013). More dental anomalies are represented in the caprine mandibles (n=2), where the alveolus for the permanent second premolar has a socket for a second root on the buccal side, and where the lower second molar has an extra enamel lobe in the posterior cusp (Russell *et al*. 2013).

The sheep metacarpus in which the articular surface of the lateral condyle of the distal end is extended to the lateral presumably also exemplifies a congenital anomaly, as no signs of inflammation are visible (Russell *et al*. 2013).

Oligodonty, in the form of the lack of second permanent premolar in a cattle mandible, and specifically aurochs, is also noted in the Late Neolithic assemblages (Pawłowska in press). Other congenital defects refer to caprine mandibles, in which an accessory foramen is observed in various locations (below dp2, dp3, P3/P4, P4), though generally below the premolar row (n=1 (TP Area); n=5 (TPC Area)).

Table 2.10. Çatalhöyük East: Taxonomic and skeletal distribution of congenital anomalies.

	Sheep	*Caprine*	*Cattle*	*Total*
Neolithic (early levels)	3	3		6
Mandible	2	2		4
Metacarpus	1			1
Teeth (mandibular)		1		1
Late Neolithic		4	1	5
Mandible		4	1	5
Post-Neolithic			1	1
Skeleton			1	1
Total	3	7	2	12

A special case of congenital anomaly from the post-Neolithic context is a cattle skeleton of a fetus or neonate that has two skulls with asymmetrical development of the squamous part of the occipital bones, two atlases, malformed cervical vertebrae (especially the axis), and malformation of the thoracic spine visible in the malformed and asymmetrically developed vertebrae, in the corpuses, spinous processes, and transverse processes. Altogether, 25 specimens show lesions. The axis seems to be the fusion of two vertebrae originally present during ontogenetic development, so the case involves incomplete twinning with union at the axis. All the above lesions thus result from a two-headed calf with cervical and thoracic lordosis as a consequence of what seems to be undivided twins (Pawłowska forthcoming).

2.3.5 Traumatic lesions

Fractures, crushing injuries, bone wounds, and dislocations are well-recognised types of trauma identified in archaeozoological research. They occur as a result of violent encounters with environmental hazards (Bartosiewicz and Gál 2013).

Traumatic lesions are rare in the Çatalhöyük assemblages but are seen among sheep, caprines, cattle, equids, and dogs, from both the Neolithic and post-Neolithic contexts (Table 2.11).

In assemblages from the earlier Neolithic levels, both fractures with dislocation on sheep and cattle tibias, as well as fractures without dislocations on a caprine nasal bone and equid scapula were noted (Russell and Martin 2005; Russell *et al*. 2013). All of these represent healed fractures. Cases of ossified hematoma are related to a sheep first phalanx and a caprine tibia (Russell *et al*. 2013). This lesion, which left a smooth lump on the tibia shaft, indicating a healing process, is usually the result of a contusion with the effusion of blood beneath the periosteum (Van Arsdale 1893). It also seems that the presence of exostosis on the distal end of the phalanx is a response to the contused bone injury that led to the hematoma. The smooth lump is a result of the affected area being filled with newly formed bone, affecting the density and outline of the cortical bone (Bartosiewicz and Gál 2013). Among the post-Neolithic assemblages, a dog skeleton

Table 2.11. Çatalhöyük East: Taxonomic and skeletal distribution of traumatic lesions.

	Sheep	*Caprine*	*Sheep-size*	*Cattle*	*Equid*	*Dog*	*Total*
Neolithic (early levels)	2	2		1	1		6
Proximal phalanx	1						1
Scapula					1		1
Skull (nasal)		1					1
Tibia	1	1		1			3
Post-Neolithic			1			1	2
Humerus						1	1
Rib			1				1
Total	2	2	1	1	1	1	8

shows a humerus fracture with dislocation in the middle of the shaft (TPC Area). The dog also suffered from osteomyelitis and an arthropathy, described above (Figure 2.6). A sheep-size rib provides evidence of fracture without dislocation near the rib head, with slightly spongy bone formation indicating a healing process.

2.3.6 Diseases associated with the environment

Each animal is embedded in a particular environment, of which it forms a part, and in which interactions between animals take place. Their living conditions can be associated with humans, but need not be. Diseases associated with the environment could be associated with nutrition, caused by parasites, or be the result of environmental stress.

All the Neolithic pathological phenomena discussed here result from malnutrition and a build-up of incremental structures in response to environmental stress. The first of these concerns sheep and goat horn cores that display so-called "thumbprint" depressions (Table 2.12). Several suggestions have been made to explain such indentations on the horn core, and attempts have been made to link them with various factors such as castration, genetic predisposition, malnutrition, or yoking. In his review, Albarella (1995) pointed out that horn core depressions are due to the resorption of calcium in completely developed horn cores. He suggests environmental stresses, such as malnutrition, as the most probable causes of this, which is consistent with the comments of Russell *et al*. (2013) on Çatalhöyük sheep. Repeated pregnancy and lactation, intense milking, or a combination of these factors including malnutrition have also been put forward as explanations (Albarella 1995).

The second factor behind the pathological phenomena – the build-up of incremental structures in response to environmental stress – can be illustrated by the caprine teeth (n=3) that show evidence of dental enamel hypoplasia (DEH), a permanent alteration of the tooth enamel resulting from disturbances in enamel secretion, which manifests as defects, such as lines, pits or grooves (Bartosiewicz and Gál 2013). At Çatalhöyük, DEH has been observed in the form of pitting, grooving,

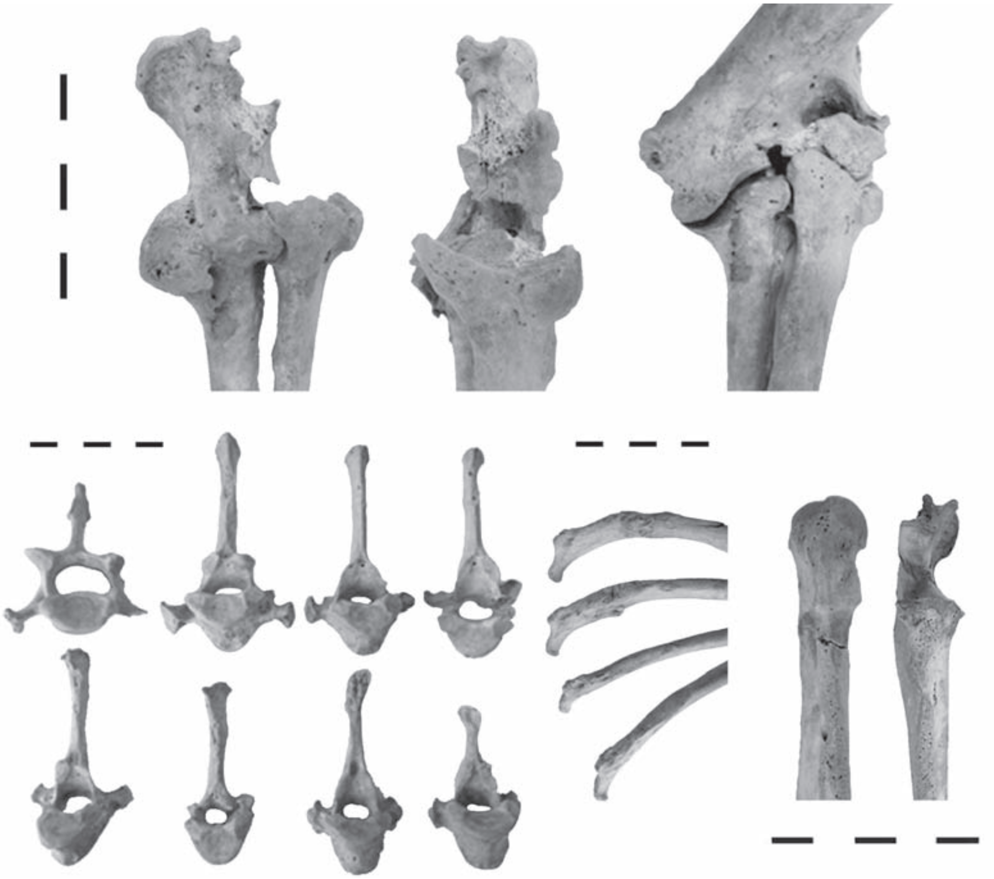

Figure 2.6. Symptoms of a disease of an elbow joint (upper row showing left proximal radius and ulna, as well as distal humerus) and osteomyelitis (lower row showing vertebrae, ribs, and right proximal radius and ulna) in a dog skeleton (Photo: K. Pawłowska).

and distorted areas in the enamel on the first and second lower molars and upper premolars (Russell *et al*. 2013).

Late Neolithic specimens showed the presence of nutritional disorders. Osteoporosis refers to the gross reduction of bone mass and may be a symptom of various disorders resulting from malnutrition, parasitism, or anemia (Bartosiewicz and Gál 2013). It was recognised on a cattle anterior first phalanx within the anterior and posterior faces right at proximal articulation (Pawłowska in press).

Finally, a patch of porous bone on the anterior surface of a cattle tibia most likely results from malnutrition.

Diseases associated with the environment have not been detected so far within the animal remains that can be dated as post-Neolithic.

Table 2.12. Çatalhöyük East: Taxonomic and skeletal distribution of diseases associated with the environment.

	Sheep	*Goat*	*Caprine*	*Cattle*	*Total*
Neolithic (early levels)	3	1	3		7
Horn core	3	1			4
Teeth			3		3
Late Neolithic				2	2
Proximal phalanx				1	1
Tibia				1	1
Total	3	1	3	2	9

2.3.7 Other

There are some pathological phenomena that could not be attributed to specific categories, and are thus collected here in a separate group (Figure 2.1). These are mostly examples of exostosis (about 67% of the pathological specimens from earlier Neolithic levels) on various elements. Some are caused by injury or are age-related (Russell and Martin 2005; Russell e*t al*. 2013).

Among the Late Neolithic pathological specimens, the exostosis seen on the first phalanx and fourth metacarpal of a stone marten is remarkable, and is likely associated with the age of the individual (Pawłowska and Marciszak 2017).

2.4 Conclusions

The pathological phenomena revealed so far at Çatalhöyük contribute to our knowledge of pathology in the past by providing interpretative potential about inherited and age-related traits, animal management and husbandry, and human-induced changes.

The presence of healed lesions indicates that at least some of the pathologies had no serious impact on the animals' conditions and that these animals survived.

Although various species are represented among the pathological specimens, they were particularly prevalent in caprine and cattle, which played a major role in subsistence strategies at Çatalhöyük.

Inflammatory diseases and dental anomalies are more frequent relative to arthropathies, congenital anomalies, traumatic lesions and diseases associated with the environment; however, it should be stressed that the presence of animal pathologies is generally low. The relative frequency of pathologically modified bones is low in both the Neolithic and post-Neolithic assemblages.

In temporal trends, the late Neolithic evidence of pathology does not differ substantially from evidence earlier in the Neolithic sequence. Attention should be drawn, however, to the complete lack of abscesses (Late Neolithic–post-Neolithic period), which could be indicative of a lack of serious inflammations in animals at this time, in particular in the oral cavity, as shown by evidence from earlier levels. This, however, would be good to develop further using a much larger dataset. Future

investigations focusing on the potential relations between the observed pathology issues and the various contexts of the finds in the framework of a more detailed approach would also be beneficial to archaeopathology studies, not only in Çatalhöyük. Moreover, well-documented cases of pathology from other sites in Turkey should allow us in future to develop a broader synthesis concerning animal diseases in Neolithic societies.

Acknowledgements

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3. Palaeopathology at the Eneolithic Tell Settlement of Polyanitsa (NE Bulgaria)

László Bartosiewicz, Éva Ágnes Nyerges and Anna Zsófia Biller

Polyanitsa was a densely inhabited Eneolithic tell settlement of eight levels. The large assemblage of over 40,000 animal remains identified by Sándor Bökönyi reflects clear diachronic trends typical of animal exploitation in the broader region, the Central Balkans and the Carpathian Basin. Reliance on domesticates, and especially caprines decreased through time. Beef dominated the diet, but there was a decline in the exploitation of sheep and goat for meat. The role of pork seems stable diachronically. The small set of 16 pathologically modified animal remains from Polyanitsa could be evaluated against the background of this information. Although the specimens available for study are too few for quantitative analyses, many fit the gross tendencies seen in the overall refuse bone material. The pathologically modified cattle bones set aside by Bökönyi show no signs of draught exploitation. Sheep morbidity may partly be attributed to environmental factors. Several bones show symptoms of infectious disease in pig. With the increase of hunting, a rare pathological case occurred even among the wild animal remains.

3.1 Introduction

The 5th and 4th millennia BC are characterised by the emergence of copper metallurgy in south-eastern Europe. During these two millennia, numerous technical developments, increasing differentiation of settlement hierarchies and social stratification took place in the region (Todorova 1978; Chapman 1990). Animal–human relationships also changed both resulting from innovations in animal husbandry and a general resurgence of hunting. The terms for the Stone, Copper and Iron Ages were first mentioned in a humble footnote by Lauritz Schebye Vedel Simonsen (1813, 76), but Copper Age was replaced by Bronze Age in Christian Jürgensen Thomsen's widely-used "Three Age" system for European Prehistory (Thomsen 1836). The concept of a distinct Copper Age as a fourth entity was proposed by Ferenc Pulszky (1884). This distinct prehistoric period is also called the Chalcolithic and the Eneolithic (*Eneolitica*), the latter having been suggested by Gaetano Chierici (1884) and widely used in south-eastern Europe.

Between 1967 and 1974, Henrieta Todorova (1933–2015) directed rescue excavations at three prehistoric settlement mounds and associated burial grounds in north-eastern Bulgaria. These three sites were Golyamo Delčevo (Varna district), and Ovčarovo as well as Polyanitsa (Tărgovište district). The total excavation of these tell sites revealed their

carefully laid out internal structure and previously unknown defence systems indicative of highly structured communities of approximately 120–150 people (Chapman 1989). Extensive research also allowed the precise periodisation of the Eneolithic in Bulgaria, with the Middle Eneolithic represented in Thrace by Karanovo V, and the Polyanitsa culture in north-eastern Bulgaria investigated by Todorova (1982).

Until recently, tells were seen as isolated self-standing habitations while, in fact, they represent eminent centra within complex settlement hierarchies. Since no archaeozoological data are available from the surroundings of Polyanitsa, this study will focus on animal bones from this particular type of stratified settlement.

The predominantly early and middle Eneolithic settlement mound of Polyanitsa was uncovered during the last two years of this large-scale project (1973–1974). Sándor Bökönyi identified the assemblage of over forty thousand animal remains within the framework of a cooperation between the Bulgarian and Hungarian Academies of Sciences. He published, however, only preliminary results (Bökönyi 1988). He also set aside a number of bones showing pathological lesions, currently stored at the Institute of Archaeology of the Hungarian Academy of Sciences in Budapest. This report is a summary of these finds in light of archaeozoological information available from the site. Special attention was paid to the general discussion of the entire archaeozoological material given the importance of Polyanitsa in the regional network of Eneolithic settlements.

3.2 Site location, architecture and chronology

Polyanitsa is located 6 km west of the modern city of Tărgovište (43° 15' 33"N; 26° 35' 21"E) on the Polyanitsa-plateau at *c.* 250 masl, near the north-western foothills of the low Preslav range (600–700 m) in the proximity of the Vrana River. Centuries of house destruction and levelling deposits formed an almost three-metre-thick cultural layer at this settlement. Successive phases of reconstruction helped to maintain community residence through this extensive time period.

Although much of the material still awaits analysis, Todorova (1982) published plans of individual horizons. The earliest settlement occupied a rectangular area measuring 36 × 39 m. Even this very first level was fortified by a timber palisade system prior to the construction of residential buildings. The layout was strictly organised following straight streets, oriented in the cardinal directions that separated "neighbourhoods" of oblong houses. In younger levels, this design became even tighter in response to the living area progressively decreasing toward the top of the tell. Houses followed the strict rectangular order as the ratio of built surface increased diachronically. According to John Chapman (1989), in contemporaneous single-layer settlements in Bulgaria, the ratio of built to unbuilt space varied between 1:30–1:13. At the tells of Ovčarovo and Polyanitsa, on the other hand, this value ranged between 6:1–1:1, reaching even 8:1 at some levels. High population density required a stable food supply secured by agricultural production, including animal husbandry. However, the crowded houses evidently left no room for animal keeping within the tell, a site of consumption rather than production from an archaeozoological point of view.

The houses were divided into numerous rooms, many with several doors. This high degree of spatial differentiation has been interpreted as a reflection of social complexity mirrored by the carefully sub-divided internal spaces with specialised functions (domestic, ritual, communal and craft activities) conducive to a range of "polluting" behaviours – a potential source of daily conflict (Chapman 2010, 80). Omnipresent food refuse, indicated by the quantities of animal bone recovered, may have been a persistent problem even if its stench was tolerated at the time (Bartosiewicz 2003, 189). Pawłowska (2014) directed attention to the importance of architecture in determining air pollution at Neolithic Çatalhöyük. Smells could derive from piles of decaying household waste and feces. In the Polyanitsa habitation area at least dung pollution may be discounted in the likely absence of herds within the tell. Even the regular on-site slaughter of livestock may be questioned. On the other hand, the tightly packed buildings with poorly ventilated rooms and the use of indoor hearths exacerbated the situation.

Settlement first took place at Polyanitsa in the Early Eneolithic but persisted, possibly without interruption, until the late Eneolithic when the village was burnt and the inhabitants left. Occupation thus occurred in the late 5th and first half of the 4th millennium BC. In typochronological terms, this corresponds to levels IV–VI at Karanovo in Thrace to the south (Manhart 1998, 16) and the Boian III (4100–4000 BC)

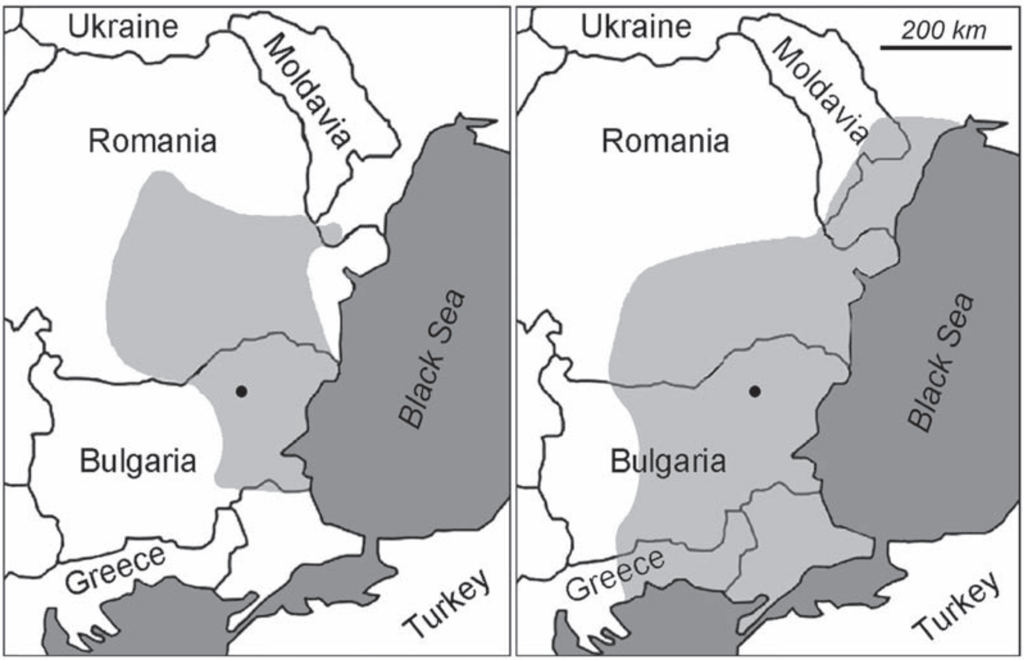

Figure 3.1. The location of the site marked by a black dot within the distribution areas of the Boian-Karanovo V (left) and Kodžadermen-Gumelniţa-Karanovo VI (right) cultural complexes indicated by shading.

and transitional Boian-Gumelniţa cultures (4000–3500 BC) in Romania to the north. The geographical distributions of relevant archaeological cultures across present-day political borders in relation to the location of Polyanitsa are shown in Figure 3.1.

3.3 Material and methods

Excavations at Polyanitsa yielded the highest number of Eneolithic animal remains in the region (Manhart 1998, 221, tab. 50; Bréhard and Bălăşescu 2012, 3173, tab. 3): Bökönyi (1988) published a summary of 40,593 identifiable specimens (NISP) by eight levels. Although no relevant record is available, one may safely assume that the material was hand-collected since screening or water-sieving were rarely employed in Eastern Europe at the time. In a way, this makes the high NISP even more impressive. Since the lack of fine recovery methods tends to primarily bias assemblages of small vertebrate taxa (fish, birds and micro mammals), Bökönyi's 1988 results concerning domestic mammals and large game can be considered reliable.

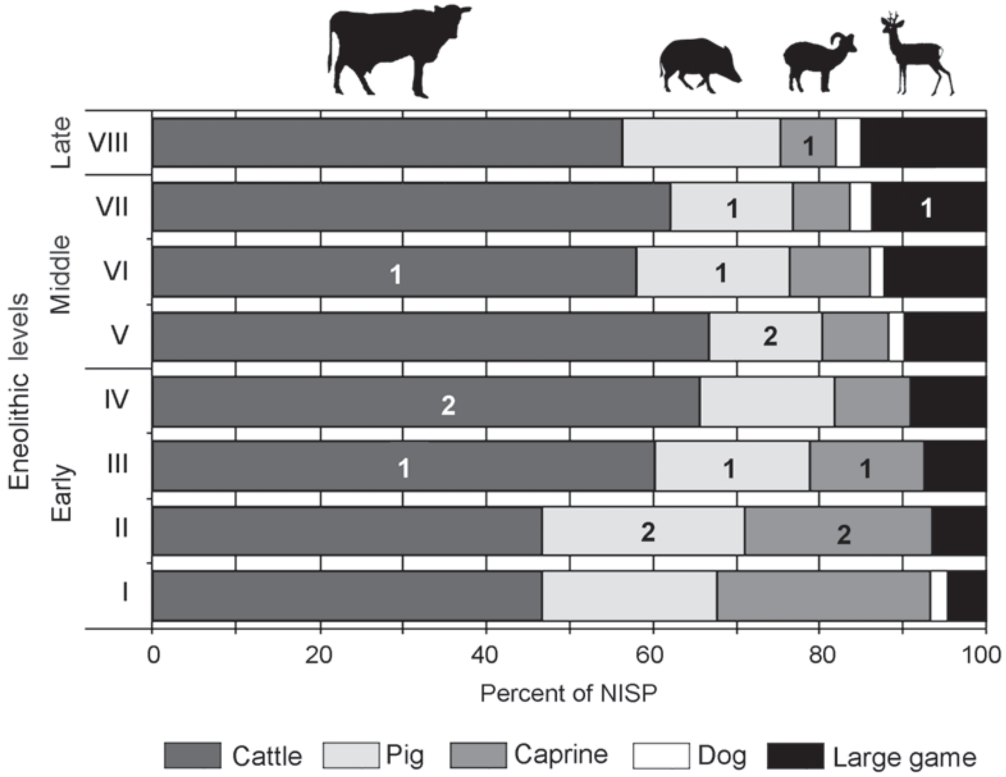

Figure 3.2. The relative frequencies of bone fragments from domestic and game animals in various levels of the Polyanitsa tell (raw data after Bökönyi 1988). Figures within the diagram stand for numbers of pathological specimens.

Although no radiocarbon dates are available from Polyanitsa, its internal phasing may be outlined as follows:

- Early Eneolithic: Levels I–IV
- Middle Eneolithic: Levels V–VII
- Late Eneolithic: Level VIII (the top)

Bökönyi's 1988 publication is focused on percentages of animal remains: the level-by-level absolute numbers of identifiable bones thus remain unknown. One may only conclude, that even the sub-assemblages were reasonably large, although the top layer of the tell was poorly preserved and probably few bones survived in it (John Chapman, pers. comm.). The relative frequencies of bone fragments from domestic and game animals in various levels of the Polyanitsa tell are shown in Figure 3.2.

The emergence of the tell was accompanied by gradual changes in meat consumption. The most consistent diachronic trend is that hunting played an increasing role in meat procurement at the expense of early caprine herding. The relative contribution of pork to the diet seems to have been almost constant. These gross trends will be reviewed in regional context in the discussion below.

3.4 Results

Considering the large size of the Polyanitsa animal bone assemblage, the 16 pathologically-modified remains set aside by Bökönyi is a very small set, most notably in the case of cattle, whose remains dominate at each level. Taxonomic composition is better reflected in the cases of caprines and game whose sporadically found pathological specimens concur with the main trends shown in the NISP percentages. The stable ratio of pig bones through time coincides with the best representation of this species in the small palaeopathological assemblage (Table 3.1). The small numbers of pathological lesions seem to indicate that Bökönyi retrieved only the most spectacular pathological specimens for additional study; the cases documented here allow thus qualitative rather than far-reaching quantitative conclusions. Pathological specimens identified in this material will be presented by level, following a progressive chronological order.

3.4.1 Early Eneolithic

The taxonomic compositions of Levels I and II were similar, but no pathologically modified animal remains are available from Level I. The relative contribution of caprine remains was highest in these earliest periods (20–25% of NISP). Remains of adult sheep included a heavily swollen right mandible fragment showing grave symptoms of parodontal disease (Figure 3.3, left; the M_3 tooth was broken *post mortem*). This form of chronic alveolar osteomyelitis is caused by bacterial infections turning chronic. The lesions are usually concentrated in the region between the P_4 and M_2 teeth, with a special predisposition of the M_1 (Bartosiewicz 2008, 4).

Table 3.1. The taxonomic and stratigraphic distribution of pathological specimens available from Polyanitsa.

Level	*Cattle*	*Pig*	*Sheep*	*Roe deer*	*Total*
VIII			ulna showing arthrotic necrosis		1
VII		scapula with deformed articular end		scapula with arthrotic symptoms	2
VI	phalanges fused after traumatic infection	acetabulum filled with massive exostoses			2
V		rotated maxillary premolar + acetabulum with exostoses			2
IV	distorted horn core + overgrown lower molar				2
III	metatarsal with periostitis	scapula with arthrosis	metatarsus with haematoma and dislocation		3
II		maxilla with oligodonty + healed humerus fracture	mandible with ginvitis + arthrotic proximal phalanx		4
Total	4	6	5	1	16

Inflammation of the gingivae damages the tooth sockets. Ultimately, teeth are lost and the alveolus is remodelled (Lane 1981). *Intra vitam* loss of the M_1–M_2 tooth in the Polyanitsa case may thus be seen as typical. It is the extent of the lesion that is remarkable. Even a fistulated abscess is visible on the buccal side of this bone where the build-up of liquefied tissue (*i.e.* pus) inside the bone broke to the surface. Archaeological cases of parodontal disease are most common in caprines: 4200 toothrow fragments from a variety of assemblages in Romania revealed six cases of sheep, two of red deer, and only single examples of cattle, pig and horse (Haimovici and Haimovici 1971, 261–266, figs. 1–11). A less advanced case, similar to the Polyanitsa sheep mandible, is known from the Karanovo tell (Bökönyi and Bartosiewicz 1998). A comparable ruptured abscess was noted in the buccal area between the P_4–M_1 teeth of a Copper Age sheep from Horum Höyük, south-eastern Anatolia (Bartosiewicz 2008, fig. 2.3).

A less extreme-looking lesion in Level II was observed on the anterior proximal phalanx of another sheep. This bone was deformed by arthrotic exostoses on the articular proximal end, especially on the abaxial side. Ligamentous ossification is visible on the side of the toe, possibly caused by a wrench or twist to the ligaments that caused swelling but not dislocation. This ossified ligament formed an exostotic ridge on the

Figure 3.3. Early Eneolithic sheep remains (Level II). Right mandibula fragment showing grave symptoms of gingvitis including intra vitam tooth loss and fistula formation (aspects: a=occlusal, b=buccal). Anterior proximal phalanx deformed by arthrotic exostoses on the proximal end and both sides (aspects: c=proximal, d=dorsal, e= abaxial, f=palmar, g=axial). Scale=50 mm.

axial side of this phalanx (Figure 3.3, right). These are not symptoms of debilitating lameness, but are indicative of strain on the articulation in combination with old age. The proximal phalanx is highly predisposed to arthropathies. A dominant one quarter of 42 such lesions in caprines occurred on this phalanx in the meta-analysis of 36 prehistoric assemblages (total NISP=610,657) from Central Europe and the Near East (Bartosiewicz 2008, Table 2.3).

Level II also included two pig remains of interest. One of these is a left maxilla fragment of an adult domestic pig displaying congenital oligodonty: the M^3 tooth of this individual is completely missing. The M^1–M^2 teeth are intact (Figure 3.4, top). Archaeologically documented oligodonty in pig is usually expressed in the inherited absence of P_1 teeth, affecting one-quarter or even one-third of mandibles in certain assemblages of considerable sizes (Bartosiewicz 2013, 198, fig. 171). Maxillary oligodonty, especially the absence of the M^3 tooth, is far less known. In the absence of reference data for wild boar oligodonty has been attributed to domestication, even inbreeding. Domestication probably began with the taming of and selection for docile individuals characterised by low metabolic rates, inadvertently perpetuating inherited thyroid hormone deficiency (*hypothyroidism*) effecting growth and development. This may indeed be a factor behind the shortened facial features of many domesticates leading to both the absence and crowding of cheek teeth.

The other Early Eneolithic pig bone from this level shows a well-healed spiral fracture. It is a left humerus that healed completely with only minor *dislocatio ad axim*. The simple fracture was not infected, mild exostoses grew on the bone only to a negligible extent (Figure 3.4, bottom). A pig left scapula recovered from Level III was deformed by arthrotic lesions of the glenoid surface, showing heavy exostotic lipping

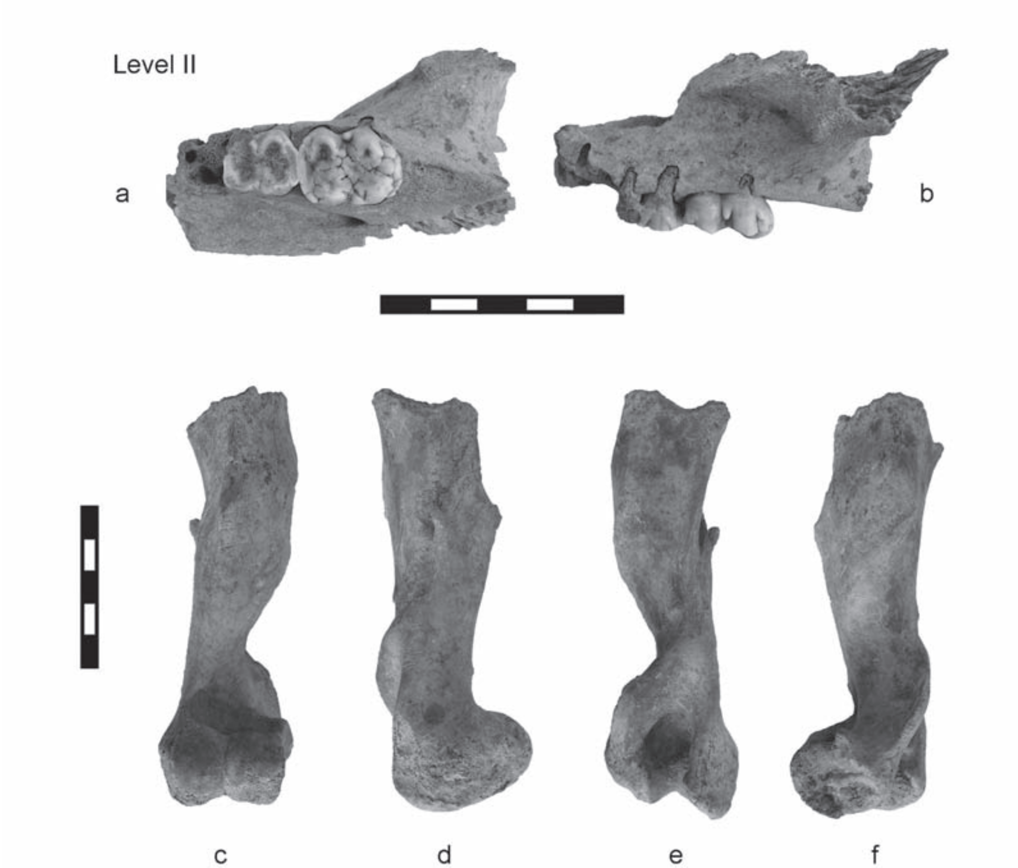

Figure 3.4. Early Eneolithic pig remains (Level II). Left maxilla fragment showing congenital oligodonty: the M^3 tooth is completely missing (aspects: a=occlusal, b=buccal). Spiral fracture on a left humerus healed with only minor dislocatio ad axim and exostoses on the medial side of the diaphysis (aspects: c=anterior, d=medial, e=posterior, f=lateral). Scale=50 mm.

on the joint's ventral edge. The more detailed examination of these lesions, however, was hindered by marks of *post mortem* dog gnawing in the same, distal part of the bone (Figure 3.5, left)

Level III also yielded a complete left metatarsus of and adult ewe. This bone was distorted by a haematoma attributable to the traumatic contusion of soft tissue adjacent to bone, which causes localised inflammation under the periosteum and heals through secondary ossification.

A slight *dislocatio ad axim* remained after the healing process. Moreover, an exostotic ridge developed along the edge of the medial plantar surface. What makes this find interesting is the relatively small degree of distortion and the almost intact bone surface

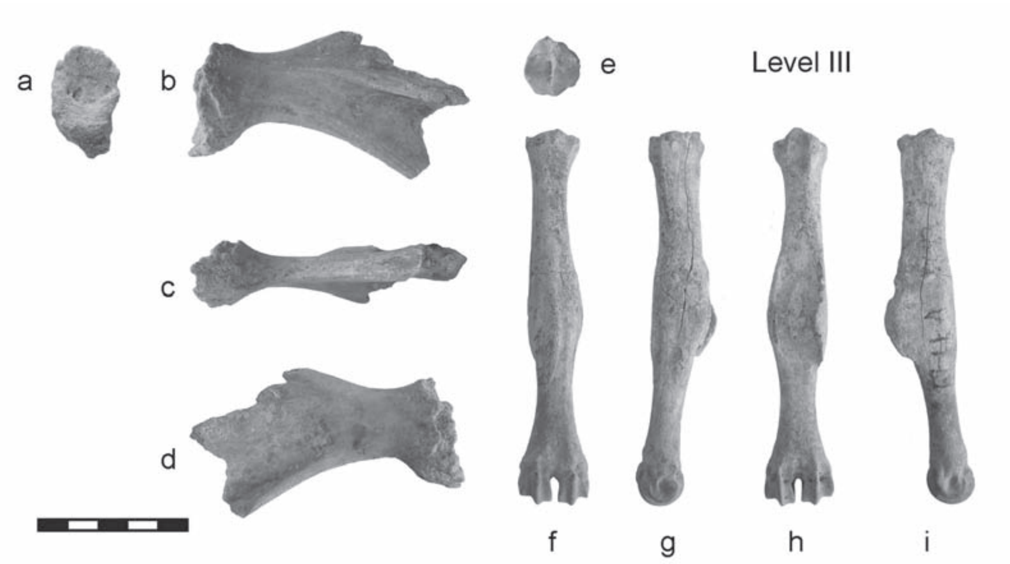

Figure 3.5. Early Eneolithic remains (Level III). Pig left scapula deformed by arthrotic lesions of the glenoid surface (a), showing heavy exostosis on the joint's ventral edge (aspects: b=lateral, c=ventral, d=medial). Sheep left metatarsus showing haematoma and slight dislocatio ad axim (aspects: e=proximal, f=dorsal, g=lateral, h=plantar, i=medial). Scale=50 mm.

indicating that the periosteum remained intact. The lesion is therefore the probable consequence a greenstick fracture which healed at a young age (Figure 3.5, right).

The right metatarsus of an adult cattle found in Level III showed symptoms of chronic periostitis along most of the lateral side except for the articular surface (Figure 3.6). Osteophytes may also be visible on the plantar surface on the medial side of the diaphysis. However, it is the area of the laterally-located fourth metatarsus, which developed a woodbark-like osseous mass of exostoses. This excess bone growth is indicative of osseous metaplasia of the connective tissue, provoked by the septic inflammation of the thin, soft tissue between the skin and periosteum, usually caused by *pyogene* bacteria. The primary cause of such chronic infections may be skin injury. Small osteophytes may be reabsorbed during this process, but large ones are converted from woven to lamellar bone and persist. Early Eneolithic Level IV showed one of the highest percentages of cattle NISPs (65%). Two of the rare pathological specimens from this species came to light here. One of them was the gravely disfigured left horn core of an adult cow. It could only be identified on the basis of the relatively healthy horn core base. The distal two-thirds of the bone, however, was deformed by probable young age trauma which compromised the growth process (Figure 3.7, left). There is a stress-related indentation in the middle of this horn core marked by a significant thinning (and eventual post-depositional perforation) of the osseous material. The tip became flat and strangely forked, reminiscent of some forms of four-horned sheep

Figure 3.6. Early Eneolithic remains (Level III). Right metatarsus of a cattle deformed by extensive periostitis on the surface (aspects: left=dorsal, right=plantar). Scale=50 mm.

in shape (*cf*. Daróczi-Szabó and Daróczi-Szabó in this volume). However, this curious form seems to be related to the disturbed healing/growth of the horn core as is also shown by patterns of irregular bone remodelling on the aboral side of the flat, double tip.

The same level contained a left mandibula fragment from cattle with an overgrown M_1 tooth (*exsuperantia dentis*), protruding from the normal occlusal line. Symptoms of mild gingvitis developed in the adjacent bone (Figure 3.7, right). Such uneven tooth growth is far more characteristic of equids than bovids (Bartosiewicz 2013, figs 142, 144). This case in cattle is probably caused by the fracture or complete absence of the opposing maxillary M^1 which precluded wear on its mandibular counterpart shown in Figure 3.7. A loss of harmony between the upper and lower occlusal surfaces may have resulted in chronic irritation leading to symptoms of periodontal disease on the mandibular alveolus, especially on the buccal side.

3.4.2 *Middle Eneolithic*

Another pathologically modified cattle bone was set aside from Middle Eneolithic (Level VI). The anterior proximal and medium phalanges of this individual are completely fused. Owing to the distortions caused by this ankylosis, it is impossible to tell whether the bones originate from the axial or abaxial extremity ray. The anterior surface and both sides of the two bones are united by a thick exostotic crust. The palmar surface is somewhat less affected, but even here the two phalanges cannot be distinguished from each other. Judged by the overall shape, the proximal phalanx may have been shortened. A fistula is visible on the anterior surface. It is located more-or-less at the damaged articulation between the two bones. This symptom is indicative of intra- and extracapsular joint inflammation that caused regressive changes in the articular cartilage. On the other hand, the joint surfaces at the proximal and distal ends of this solid block look largely unaffected, these articulations apparently retained a degree of mobility (Figure 3.8). Chronic degenerative joint disease or trauma (such as a gravely infected compound fracture) may likewise result in this type of excess bone growth which helps stabilise the disabled joint. Ankylosis between the proximal and medium phalanges is called high ring bone in

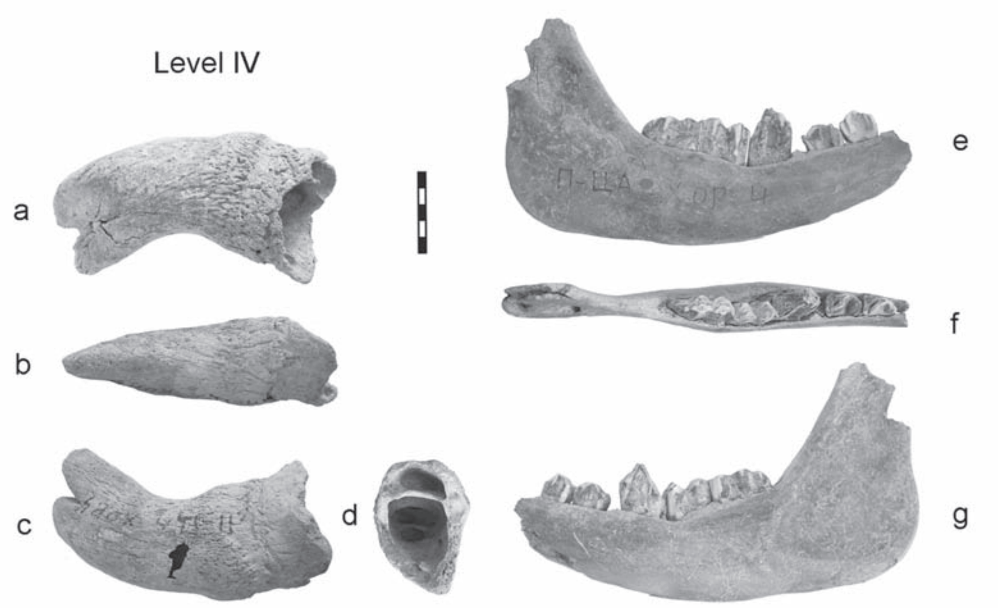

Figure 3.7. Early Eneolithic cattle remains (Level IV). Left horn core deformed possibly by young age trauma. The tip became forked and flat and, an indentation developed around the horn toward its base where the bone became very thin (Aspects: a=aboral, b=occipital, c=frontal, d=horn core base). Left mandibula with overgrown M_1 tooth and mild gingvitis in the corresponding area (Aspects: e=lingual, f=occlusal, g=buccal). Scale=50 mm.

horse. It is not only well known in equine veterinary practice (Kardeván 1976, 630, fig. 602), but also on subfossil equid phalanges (*e.g.* Iron Age Skedemosse, Sweden: Boessneck *et al*. 1968, 41, Abb. 10–11; 8th–7th-century BC Tepe Nush-i Jan, north-western Iran: Bartosiewicz 2013, fig. 105). This grave condition, however, seems to be rare in even-toed ungulates.

Middle Eneolithic pig remains include a right maxilla fragment with a rotated P^4 tooth (Level V; Figure 3.9, left). Given the previously discussed case of pig maxillary oligodonty in Level II (Figure 3.4, top), this dental anomaly may also be considered a non-pathological symptom of facial shortening, a sign of relatively advanced domestication. A right scapula fragment from a young individual (Level VII; Figure 3.9, right) is of more interest from a palaeopathological point of view. The glenoid end of this bone was completely destroyed by a necrotic process and is distorted by amorphous exostoses. There is no sign of major trauma on the remaining bone. As the regression or even necrosis of articular cartilage accompanying tuberculosis has commonly been observed in cattle and pig, one might wonder, whether this case is at all related to the two Middle Eneolithic pig right pelvis fragments (Levels V and VI) shown in Figure 3.10. The acetabula of these bones are filled with new bone in both

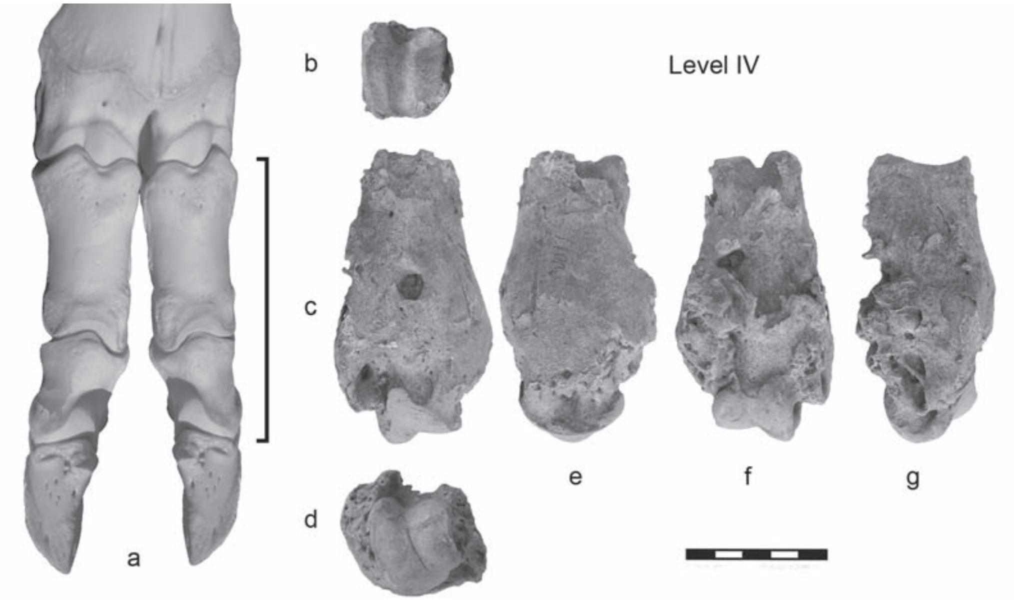

Figure 3.8. Articulated cattle foot bones (present-day reference specimen: a) with healthy phalanges and Middle Eneolithic (Level VI) cattle anterior proximal and medium phalanx fused as a result of chronic inflammation (Aspects: b=proximal, c=anterior, d=distal, e= abaxial, f=palmar, g=axial). Scale=50 mm.

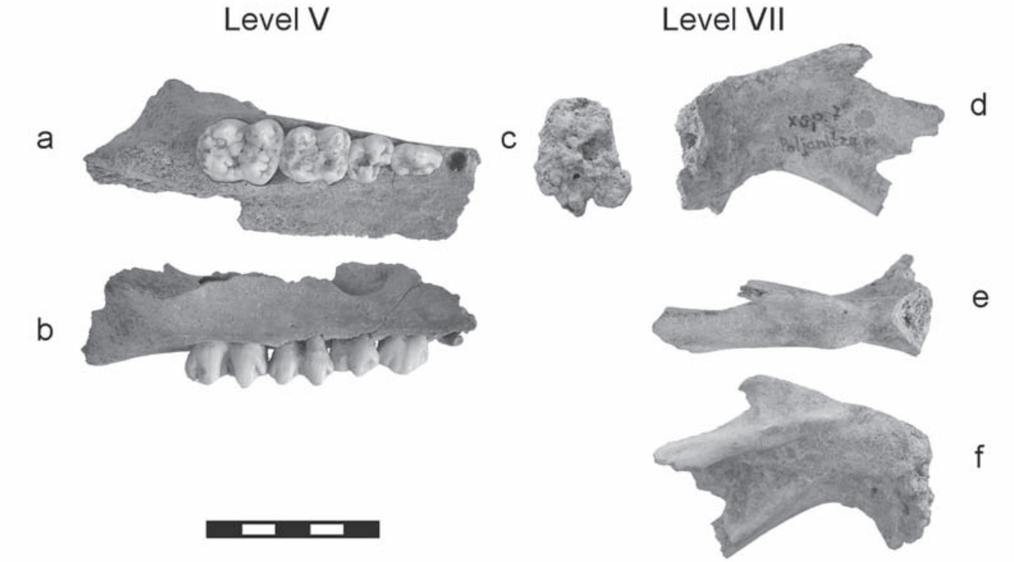

Figure 3.9. Middle Eneolithic pig remains (Levels V and VII). Right maxilla fragment with congenitally missing M^3 and rotated P^4 tooth (Aspects: a=occlusal, b=buccal). Right scapula fragment from a young individual. The glenoid end was completely destroyed by a necrotic process (Aspects: c=distal, d=medial, e=dorsal, f=lateral). Scale=50 mm.

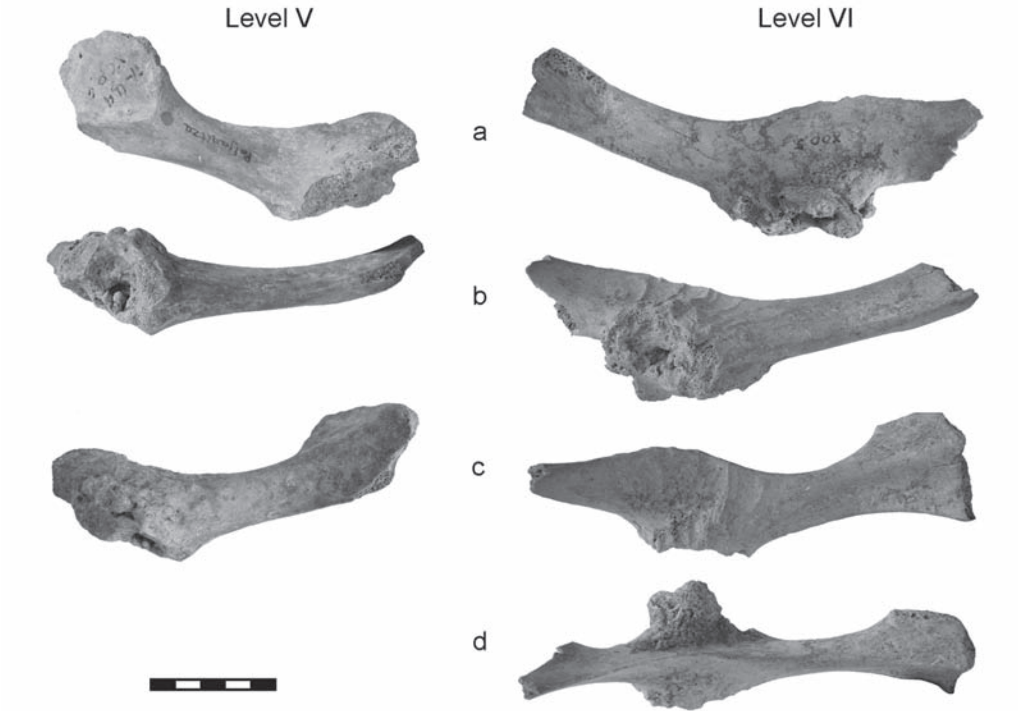

Figure 3.10. Middle Eneolithic pig right pelvis fragments (Levels V and VI). The acetabula are filled with exostoses in both cases. At the more advanced stage (right) the dislocated femur created eburnation on the medial side of the exostotic surface (Aspects: a=medial, b=ventral, c=lateral, d=dorsal). Scale=50 mm.

cases. Chronic miliary tuberculosis (spread by the blood from a centre of infection in the body producing small tubercles in other parts) is known in domestic pig. In such cases epiphyseal trabecular bone and granulation tissue of the synovial membrane progressively destroy and replace articular cartilage (Nieberle and Cohrs 1970). At the more advanced stage (Figure 3.10, right) the dislocated femur even created eburnation on the medial side of the exostotic surface. A parallel to this condition was seen on the dislocated right hip joint of a subadult pig at the 8th-century settlement of Dunaújváros–Alsófoki-patak, Hungary. The newly formed tissue was dense enough to serve as a secondary articular surface for the femur as shown by the advanced eburnation (Bartosiewicz 2013, fig. 82).

The only pathologically modified wild animal bone came to light from Level VII. It is the distal fragment of the left scapula from a roe deer showing probably age-related, isolated lipping on the medioventral side of the glenoid surface where mechanical loading of the joint is greatest (Figure 3.11, top). Minor trauma may also have contributed to the development of this exostosis.

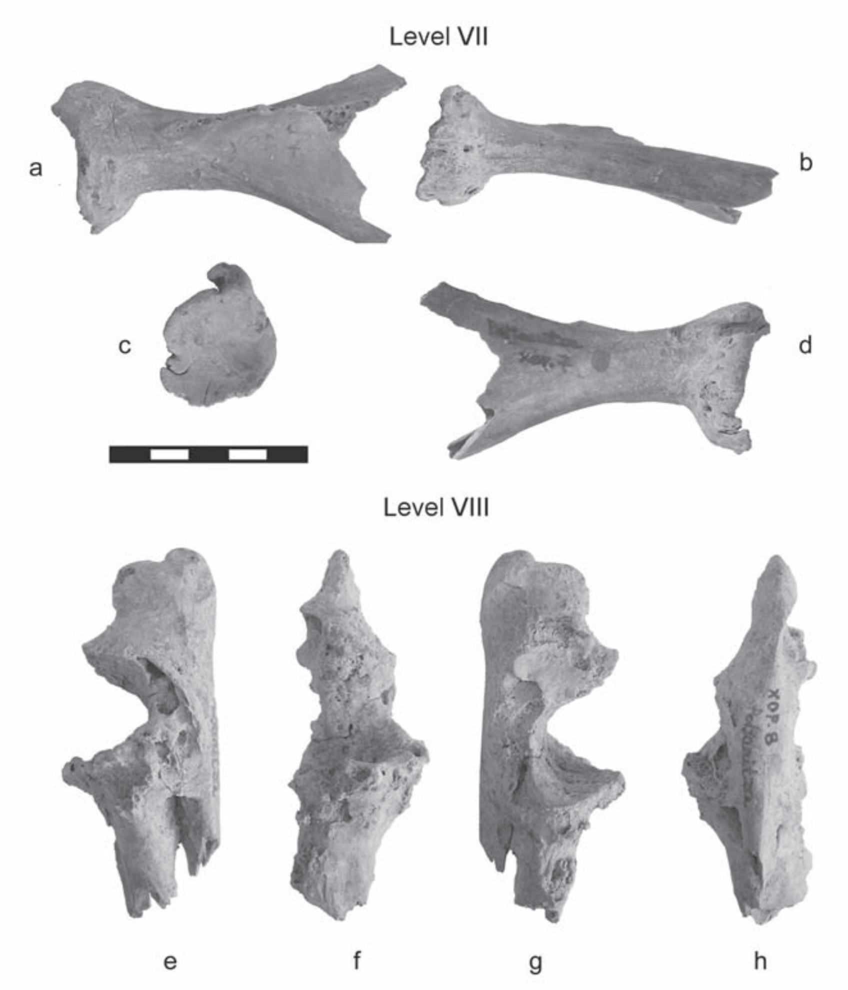

Figure 3.11. Middle Eneolithic (Level VII). Roe deer, left scapula distal fragment showing exostoses, especially on the medioventral side of the glenoid surface (Aspects: a=lateral, b=ventral, c=distal, d=medial); Late Eneolithic (Level VIII). Sheep right radiocubitus fragment showing grave inflammation of the elbow joint (Aspects: e=medial, f=anterior, g= lateral, h=posterior). Scale=50 mm.

3.4.3 Late Eneolithic

The presumably small and poorly preserved assemblage from the uppermost layer at Polyanitsa is represented by a single specimen among the pathological remains. The material from Late Eneolithic Level VIII yielded a sheep right radiocubitus fragment showing grave inflammation of the elbow joint (Figure 3.11, bottom). Even necrotic deformation is visible on the articular surface of the *incisura semilunaris* and the edges of articulations are covered by exostoses. As was the case with phalangeal exostoses, arthritic deformations occur commonly in the elbow joints of Neolithic caprines

(Bökönyi 1992). Such lesions were observed on the proximal ends of both radius and ulna in 11 of the 42 arthritic cases in the aforementioned study of 36 sites in Central Europe and the Near East (Bartosiewicz 2008, tab. 2.3). The front limbs carry, on average, two-thirds of the live weight in domestic ungulates which may be a predisposing factor in old individuals, especially in stressful environments.

3.5 Discussion

Pathological finds from the Polyanitsa tell are worth reviewing in light of main trends in Neolithic and Eneolithic animal exploitation in the region. A recent meta-analysis of 154 settlement assemblages from the Carpathian Basin and the northern Balkans (Bartosiewicz 2017) reconfirms diachronic tendencies seen across the Polyanitsa stratigraphy. According to the refuse bone material, the importance of mutton was gradually overshadowed by beef consumption. In another dimension, however, the complementary roles of domestic bovids (cattle/caprines) in meat provisioning lost ground to large game (aurochs, cervids, wild pig) in the latest periods. Domestic pig and dog did not stand out in that analysis as their overall presence did not show marked diachronic oscillations in the discussed periods, also reflected in the stable proportion of pig bones at Polyanitsa.

3.5.1 Meat consumption at Polyanitsa in regional context

The refuse bone material from Early Eneolithic strata at Polyanitsa (Levels III–IV in particular), perfectly corresponds to the Boian culture component of Măgura Gorgana near Pietrele in Romania, with a primary focus on cattle, while pig and caprines are represented by comparably small portions (*c*. 15%). The contribution of wild mammals is less than 10% (Benecke *et al*. 2013, 182). Identical percentages are shown in a cumulative graph based on several Boian culture settlements (NISP=14,285) from the rest Romania, not including Pietrele–Gorgana (Bréhard Bréhard and Bălăşescu 2012, fig. 2). Of the contemporaneous assemblages in Bulgaria, Early Eneolithic levels at Polyanitsa are most comparable to those in the Karanovo V habitation layers of neighbouring Tărgovište and Drama (Manhart 1998, 221, tab. 50).

This uniformity is replaced by remarkable diversity in the Middle and Late Eneolithic strata of tell settlements in the region. The contribution of game to the diet peaks at only 15% in Level VIII at Polyanitsa, not reaching the extremes observed at Durankulak, or indeed Ovčarovo and Golyamo Delčevo, two other tells in Todorova's project, where the percentage of wild animals ranged between 30–48% throughout the Eneolithic (Manhart 1998, 221, tab. 50). Cumulative data on wild animals also exceed 35% in Gumelniţa culture assemblages in Romania (total NISP=45,558; Bréhard and Bălăşescu 2012, fig. 2), not including Pietrele–Gorgana. At this large, western tell of the Kodžadermen-Gumelniţa-Karanovo VI cultural complex, only 50% of the remains originated from domesticates, among which pig became most important, possibly explained by the lacustrine environment of the tell (Benecke *et al*. 2013, 182). The decrease in the consumption of mutton is remarkable at most tells.

The resurgence of hunting during the Eneolithic is still poorly understood. It is in part attributed to a demonstrable shift to a cooler climate. However, it was probably also influenced by variegated interactions between societal factors, also expressed among others in the emergence of tells. In addition to the differentiation in settlement hierarchies, developments in animal husbandry and the increasing appreciation of hunting as a form of social self-representation also need to be considered. The latter is supported by the concentration of wild animal remains at the Polgár–Csőszhalom tell (Hungary) in comparison with the adjacent horizontal settlement (Raczky *et al*. 2002).

Dog remains correlate with those of game, an apparent trend already during the Late Neolithic (Bartosiewicz 1994; 2005). In addition to the theoretical possibility that dogs served as hunting companions, osteological evidence shows that they were eaten as meat from a broader spectrum of animals was consumed.

3.5.2 Implications for palaeopathology

Pathologically modified specimens detailed in the description of results are summarised by the taxonomic and stratigraphic distribution of gross categories of pathological conditions (Table 3.2). In palaeopathology, precise diagnoses are often impossible to make due to equifinality, *i.e*. morphologically similar lesions being caused by very different pathogens. This summary, however shows that different groups of animals suffered from different conditions at Polyanitsa. Trauma, a category perhaps most readily identifiable, was observed in all domesticates. In fact, this was the only type of disease identified in cattle. In addition to bone fracture, sheep showed symptoms of inflammations possibly related to the environment. Pig bones on the other hand displayed non-pathological, inherited dental anomalies and signs of generic infection, possibly tuberculosis in addition to the traumatic case.

Table 3.2. The taxonomic and stratigraphic distribution of probable pathological conditions observed at Polyanitsa.

Level	*Cattle*	*Pig*	*Sheep*	*Roe deer*	*Total*
VIII			age-related + environment		1
VII		possible infection		age-related	2
VI	trauma	possible infection			2
V		inherited + possible infection			2
IV	probable trauma + tooth damage				2
III	skin/soft tissue injury	possible infection	trauma		3
II		inherited + trauma	environment + age-related		4
Total	4	6	5	1	16

Although age is not a pathological condition, it is a predisposing factor to disease. In addition to naturally strengthening degenerative processes in older animals, longevity increases the statistical probability of trauma during an individual's extended life span. Thus the age structure of assemblages may help interpreting pathological phenomena observed in the material. Bökönyi (1988, 48, tab. II) published percentage data on the age at death for domestic livestock for each level (Figure 3.12). Unfortunately, no taphonomic record is known from Polyanitsa. A greater degree of biostratinomic loss (scavenging, trampling) of tender bones, however, may contribute to the underrepresentation of non-adult age groups in such intensively inhabited spaces. The lack of sieving at the site would also impinge on the recovery of small remains from juvenile animals (*e.g.* milk teeth).

Age distributions look straightforward in cattle. Beef must have been an easily distributable staple for the concentrated human population. There is also a clear and consistent diachronic increase in the age of animals slaughtered. Longevity in this case may also be linked with secondary exploitation. Norbert Benecke (1994, 133) argues – in general terms – that the increasing age and number of cattle are indicative of dairy exploitation. Although milking had been known already during the Early Neolithic (Craig *et al*. 2005), its importance may have increased at Polyanitsa. The use of animal power would also have promoted longevity in cattle. Remarkably, however, none of the pathological deformations found on the few cattle bones are typical of draught animals. This does not exclude the use of cattle in tillage, especially given the extent of land cultivation probably needed to feed the tell's inhabitants. Use in wheeled transport can be discounted as the earliest wheel in the region was found 1200 km to the west in Slovenia. Moreover, it was radiocarbon dated to what looks the very end of occupation at Polyanitsa (Veluščček *et al*. 2009). A meta-analysis of 51 assemblages (total NISP=1,507,451) showed that prehistoric draught exploitation was less intensive (and thus less detrimental to animal health) than during the Roman Period and Middle Ages (Bartosiewicz 2006, 260, fig. 3). The difference was expressed

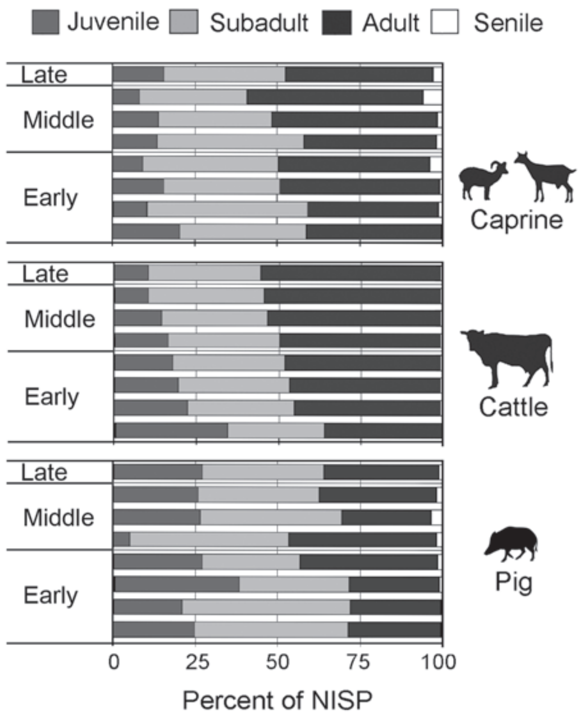

Figure 3.12. Age compositions of the main domestic animals in various levels of the Polyanitsa tell (Raw data after Bökönyi 1988).

by the changing anatomical distribution rather than increasing relative frequency of pathological lesions. Although bones in the feet of working animals frequently show chronic enthesopathies, the rare ankylosed phalanges found at Polyanitsa are indicative of a localised single trauma, not necessarily related to draught exploitation.

The scarcity of pathological cattle bone may have additional explanations. As mentioned previously, there was no place to tend livestock within the tell settlement. The possibility that slaughter or even primary butchering took place off-site is most likely in the case of this large-bodied animal. If we hypothesise that major cuts were taken inside the habitation area, it is possible that spectacularly diseased animals or heavily affected body parts were not taken into the settlement. Last but not least, given the unusually small number of cattle bones among the pathological remains, it is possible that Bökönyi did not set aside bones showing only mild cases such as rib fractures, commonly occurring in large stock.

In the case of caprines, the ratio of older animals (including senile individuals) seems to be increasing. Four Early Eneolithic pathological specimens show diverse symptoms of not only age-related disease, but also mandibular infection, possibly caused by the overcrowding of pastures and young-age trauma. These may be indicative of the environmental limitations of sheep husbandry already in the early phases of occupation.

The single sheep-bone lesion from the Late Eneolithic, however, is the chronic inflammation of the elbow joint, typical of old animals. According to Stéphanie Bréhard and Adrian Bălăşescu (2012, 3181) the relative paucity of bones from the youngest sheep and goats at tell sites in Romania may be explained by the fact that the early stages of animal husbandry (lambing/kidding in particular) took place elsewhere and caprines were brought to these settlements once they had reached their optimum slaughter weight. Indeed, given the human population density at Polyanitsa, it is possible that – as suggested with cattle – sometimes only major cuts were taken to the habitation area.

Last but not least, although according to Manhart (1998), woolly sheep was unknown during the Eneolithic of Bulgaria, decreasing mutton consumption and increasing caprine ages could be indicative of secondary exploitation for at least milk. The distribution of remains by age and sex at Pietrele–Gorgana suggests that bovids were probably also raised for milk (Benecke *et al*. 2013, 182).

Pig remains show an unusually high contribution of bones from adult and even senile individuals. As a single-purpose meat animal pig is usually characterised by younger age cohorts than seen at Polyanitsa. One explanation may be the maintenance of a viable breeding stock, *i.e.* not killing animals before most of them had reproduced. Higher age is consonant with the unusually high representation of pig remains in the small pathological assemblage. Of all livestock omnivorous pigs are best known to have been tolerated within the boundaries of human habitation (Bartosiewicz 2003). Even if this was unlikely at Polyanitsa given the density of houses, symptoms of tuberculosis are indicative of keeping that was concentrated enough to increase the risk of infection.

In spite of the increasing contribution of game to meat consumption, the role of subsistence hunting was insignificant at Polyanitsa. A single pathological specimen was found among the wild animal remains. Owing to natural selection morbidity in wild animals is smaller than in their domestic brethren (Bartosiewicz 2016). It is perhaps not

an accident that this rare case was manifested at a time when the exploitation of wild fauna increased at the settlement.

3.5.3 Quantitative aspects

The 16 pathologically-modified remains in this list make up a mere 0.037% of the total NISP at Polyanitsa. This would suggest that very few animals suffered from diseases affecting the skeleton. Jane Siegel (1976, 358, tab. 2) reported 0.24% pathological specimens on the basis of 47,300 bones from 18 sites in Britain. The ratio observed at Polyanitsa is more reminiscent of the 0.029% value published by Brian S. Shaffer and Barry W. Baker (1997, 257) in a review of 260,475 skeletal elements from prehistoric sites in the USA. This latter study, however, by definition did not include domestic livestock whose degree of morbidity tends to be greater than that of game subject to natural selection.

Cattle is evidently underrepresented among the pathologically affected remains. Thanks to the large size of the assemblage, however, the law of large numbers still seems to be manifested in the case of caprines: several pathological specimens from sheep represent conditions that occur commonly in large sets of data thus conforming to previous knowledge. The only pathological wild animal bone known from Polyanitsa originates from a latest Middle Eneolithic phase (Level VII) when hunting already gained in relative importance. In probabilistic terms, the Late Eneolithic sub-assemblage (Level VIII) was likely too small in absolute terms to allow the manifestation of additional specimens.

3.6 Conclusions

Polyanitsa was an intensively inhabited tell settlement whose inhabitants relied on animal husbandry for meat supplies even in its latest phases. Subsistence hunting became far more important at other Eneolithic tell sites in the region. Data by Bökönyi show that the mode of meat provisioning at Polyanitsa was relatively uninterrupted in comparison with those settlements, although evolutionary trends are evident in the taxonomic and age compositions of food refuse.

While the potentially pre-selected, small set of pathological animal remains is not representative in a statistical sense, the 16 specimens help highlighting some important diachronic tendencies in animal exploitation at Polyanitsa. Given the dominance of adult cattle bone in the food refuse, the marked scarcity of pathological phenomena contradicts previous experience. Even if cattle were not extensively used as beasts of burden, significantly more bone lesions would have been expected on a purely stochastic basis. It is likely that only the most spectacular cases were set aside for detailed analysis by Sándor Bökönyi.

Many remains of both caprines and pig originated from adult and even senile individuals. The pathological lesions observed parallel the general age pattern recorded by Bökönyi. In sheep, longevity – and related pathological conditions – may be interpreted as a sign of secondary exploitation. The slaughter of relatively old pigs is more difficult to explain, but is also mirrored by the unusually high proportion

of pathologically deformed pig remains. Wild animal bones rarely show symptoms of disease. Since they remained altogether underrepresented in the Polyanitsa assemblage, the single roe deer bone showing mild pathological lesions may be considered a rare find. It originates from a level in which venison was of potentially increasing importance in the diet.

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4. Pathological Observations on Mammalian Remains from the Roman Sanctuary at Carnuntum–Mühläcker (Austria)

Erika Gál and Günther Karl Kunst

Several large buildings, interpreted as two temples, banquet halls and a bath, and including a sanctuary dedicated to Jupiter Heliopolitanus, were erected at Carnuntum–Mühläcker in the 3rd century AD. Of the accompanying features, Pit G11/L29 and Pit M37 yielded animal remains displaying a variety of pathological lesions.

Pit G11/L29 contained a number of cattle ribs with arthropathies and traumatic lesions as well as vertebrae from caprines and horse exhibiting arthropathies. This pit mostly contained young animals representing food served in the sanctuary. Oligodonty and exostoses in cattle, tooth deformations in horse and dog were also identified. Given the young age of animals few pathological lesions were expected. Healed cattle rib fractures from Pit G11/L29 outnumber all other lesions. They occur mostly on caudally-located ribs and may be indicative of mistreatment. The lesions presented no obstacles for consumption. They may indicate that the cattle for the sanctuary came from a selected population. Conceivably, archaeological cattle populations could be characterised and compared on the basis of variability in pathological lesions.

Bones so far examined from Pit M37 displayed dental/oral and inflammatory diseases, as well as arthropathies and traumatic lesions in cattle, sheep, horse and dog. Remains of pig, equids and dog, rare in Pit G11/L29, were far more common here, just as in many assemblages from other parts of Carnuntum. The age distribution of animals slaughtered was also more diverse.

4.1 Introduction

During the excavations at Carnuntum–Mühläcker between 1978 and 1991, broad surfaces of a Roman sanctuary were investigated. The sanctuary was dedicated to Jupiter Heliopolitanus, an oriental deity venerated in Baalbek. The site is situated about one kilometre north east of the legionary fortress, and two kilometres from the civil town (Figure 4.1). While the first settlement phase in the area with stone-constructed buildings and a temple date to the beginning of the 2nd century AD, a major settlement reorganisation took place around the end of the second and the beginning of the 3rd century AD (Gassner *et al*. 2011).

In the 3rd century AD, several large buildings, interpreted as two temples, banquet halls and a bath, were erected in the Mühläcker area. In the archaeological record this reconstruction phase is marked by the discovery of several large pits filled with

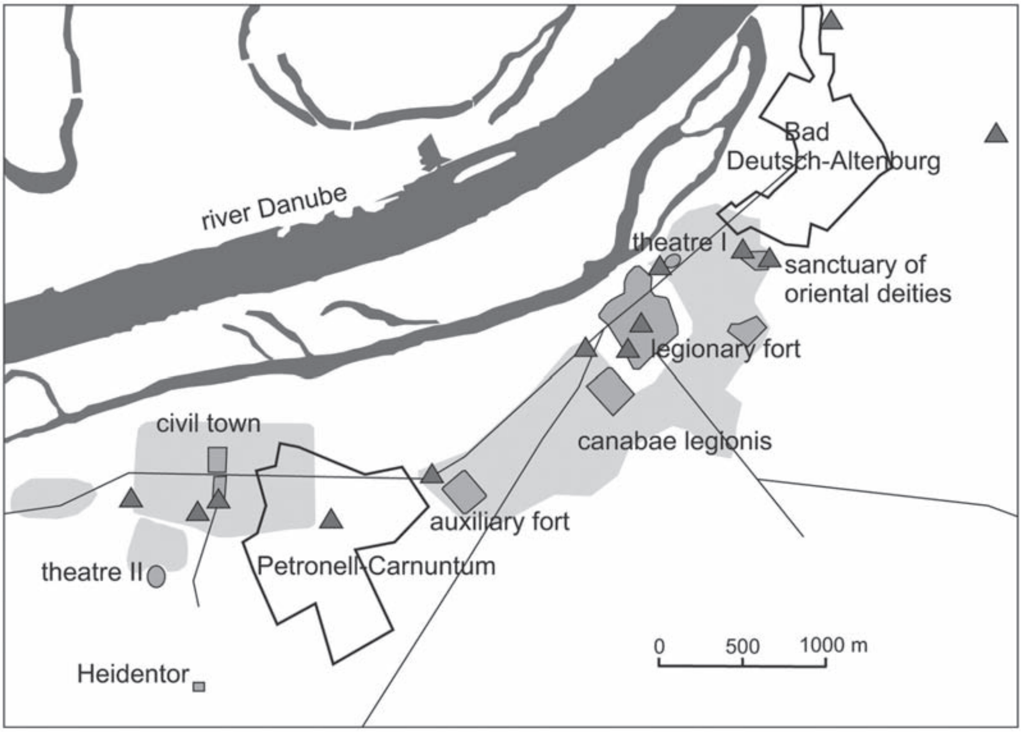

Figure 4.1. Generalised map of the archaeological area of Carnuntum. Legend: dark=water bodies; light grey=Roman settlement area; dark grey=major excavated structures; triangles=sanctuaries; fine lines=Roman roads; strong lines=limits of recent settlements; partly redrawn after Gugl and Kremer 2010.

fragments of wall paintings, pottery, and animal bones. Of these pits, Pits G7, G11/L29 and G30 (situated south of a central courtyard) yielded faunal assemblages containing bones displaying a variety of pathological conditions. The animal bones contained in the pits may represent waste from communal meals or feasts connected with activities at the sanctuary. In any case, most of the material comprises food refuse.

Pit G11/L29 produced the largest sample. The fauna is dominated by the bones of cattle and domestic fowl. The largest pit, irregularly-shaped Pit M37, was located outside the sanctuary enclosure. The faunal remains collected from this feature differ from those in the other pits. They represent a more generalised regime of disposal, comprising a mixture of food remains, dominated by the main domesticates, and dispersed parts and incomplete skeletons of dogs and, to a lesser extent, equids. There is no evidence that either of the latter two species were eaten at Carnuntum.

4.2 Material and method

In spite of the great number of animal remains brought to light at Carnuntum–Mühläcker, only two assemblages included remains displaying any kind of physical

disorder. The more abundant faunal assemblage from Pit G11/L29 (NISP=6325) yielded 22 pathological remains that represent 0.35% of the studied bones. The majority, however, were found on bird bones. There were only four specimens of pathological bone found among the mammalian bones:

- cattle (*Bos taurus* Linnaeus, 1758): mandible and a proximal phalanx
- horse (*Equus caballus* Linnaeus, 1758): tooth (M^3)
- dog (*Canis familiaris* Linnaeus, 1758): mandible

The smaller bone assemblage found in Pit M37 (NISP=2,420) yielded 26 bones showing traces of some disease, which represent 1.07% of the studied bones. The mammalian skeletal parts displaying pathological lesions include:

- cattle: two mandibles, two proximal phalanges, four medial phalanges, and one distal phalanx
- sheep (*Ovis aries* Linnaeus, 1758): two mandibles
- horse: one metatarsus
- dog: six mandibles, humerus, radius, and ulna

Following specific standards (*e.g.* Baker and Brothwell 1980; Bartosiewicz 2013), pathological phenomena were grouped into major categories according to the type and location of the pathology. There were 11 dental and oral anomalies as well as 10 specimens displaying arthropathies making these pathologies the most often observed pathological conditions. Traumatic lesions (two specimens) as well as inflammatory and inherited diseases (one specimen of each) occurred less frequently in this material (Table 4.1).

The aforementioned figures do not include elements of the axial skeleton (vertebrae, ribs, sternum) of mammals. These were studied in a separate work phase for about half of the material from Pit G11/L29. So far, 3224 axial elements were analysed, including fragments assignable to size groups only. For the sake of more detailed butchery studies (Kunst 2013, 2015) their anatomical positions were identified as precisely as possible.

The vast majority of the remains belong to cattle. The numbers of cattle vertebrae, ribs and sternum parts were 669, 2,341 and 6 specimens respectively. Among the cattle remains, pathological lesions were found on a single lumbar vertebra and on 16 rib fragments. The observations among the ribs include arthropathies (2), healed traumatic lesions (9) and probable healed traumatic lesions, indicated by irregularities on the bodies of ribs (5). Taken altogether, the pathological specimens represent 0.64% of all rib fragments. From the find numbers it becomes evident that the axial skeleton, and especially the ribs, are well represented in

Table 4.1. Distribution of main pathological categories by species.

Pathological condition	*Cattle*	*Sheep*	*Horse*	*Dog*
Dental anomalies and oral pathology	1	2	1	7
Arthropaties	9			1
Traumatic lesions	2			
Inflammatory diseases			1	
Inherited disorders	1			

Pit G11/L29. Even though only half of the material has been analysed, the number of rib fragments, compared to those of the skull and limb bones, is certainly further enhanced by fragmentation. The picture of the distribution of pathological lesions across the cattle skeleton may therefore be biased and should be treated as a rough trend only.

Among the remaining species, pathologies are limited to the vertebral column. Three equid vertebrae and three vertebrae of caprines, possibly from a single individual, exhibit slight arthropathies. The total NISP for vertebrae is only 39 for equids and 14 for caprines: percentages of pathologies are therefore higher than in cattle, but of lesser statistical relevance.

A brief presentation of the pathological conditions identified on avian remains has been recently published in a paper focusing on the exploitation of birds at this site (Gál and Kunst 2014, 340–341, fig. 6).

4.3 Results

4.3.1 Dental anomalies and oral pathology

4.3.1.1 Irregular tooth wear

Irregular tooth wear was identified on the first permanent molar (M_1) on a cattle mandible found in Sample 207–225, Pit M37. Intense pitting (of unknown origin) may be seen on the chewing surface of the tooth in addition to the heavily worn enamel (Figure 4.2). The third milk cheektooth (m_3) is still present in the alveolus, the second

Figure 4.2. Malformation in a cattle first molar (buccal aspect).

permanent molar (M_2) does not seem to have been worn at all, while the third permanent molar (M_3) is just erupting from the bone. According to the age estimation recommended by Schmid (1972, 77, tab. X) and O'Connor (1991, 250, tab. 67), this specimen may have belonged to an immature (about two years old) cattle.

Abnormal tooth wear was also recognised on two mandibles from adult sheep. The right side mandible found in Sample 236–263, Pit M37 displayed pathologies at M_1–M_2, where these teeth project above the normal occlusal wear. In contrast, the P_4 and M_1 teeth project below the normal occlusal surface on the left side sheep mandible found in Sample 188–190 from the same pit.

In addition, Pit G11/L29 yielded an upper third molar (M^3) from a horse, which was worn away slantwise in an oral direction.

4.3.1.2 Parodontal disease

The remainder of the cases in this group of pathologies represent parodontal diseases which include a rather wide range of deformations such as gingivitis, *intra vitam* tooth loss, tooth malformation, incorrect angulation and broken teeth.

Gingivitis was identified on the mandibles of two adult dogs identified in Sample 123–137, Pit M37. In the case of the first individual, the pathological condition affected the first and second molars in both mandibles. The lingual surfaces of the canines were also broken. Gingivitis appeared by the P_3 tooth in the second dog from this assemblage. In addition, broken teeth (C and P_4) were also identified in the mandibles of an old dog found in Sample 188–190 from the same pit.

The right side dog mandible from Sample 215 presented traces of *intra vitam* tooth loss. The broken root of P_4 indicates that this tooth, similarly to the other teeth in the mandible, erupted in a normal way but underwent problems during the life of the dog (Figure 4.3, bottom). A similar condition could be identified on the right side mandible of a dog found in Sample 188–190. In this case, the P_4 was broken and only the roots remained in the alveoli. In addition, the distal surfaces of the canines seem to have been partly broken in both the right and left side mandibles.

Sample 1615 from Pit G11/L29 yielded skull and mandible fragments of an adult and a *c*. six-month-old dog. The P_4 in the right mandible of the adult specimen showed incorrect angulation by growing in aboral direction towards the first molar (Figure 4.3, top).

4.3.2 Arthropathies

Each species discussed in this paper yielded a number of symptoms characteristic of joint diseases. The articular surface of a left cattle mandible found in Sample 215 of Pit M37 indicated an inflammation of the jaw joint. Instead of the rounded and smooth surface characteristic of healthy specimens, this bone developed a flat and rough surface due to deformation of the bone tissue.

Sample 236–263 from Pit M37 contained the partial skeletons of at least four dogs. Three of them were adult animals with withers heights of 34.8 cm, 56.2 cm and 58.6 cm, respectively, based on the method developed by Koudelka (1885). These sizes resemble the statures of recent breeds such as "beagle" and "pointer" respectively.

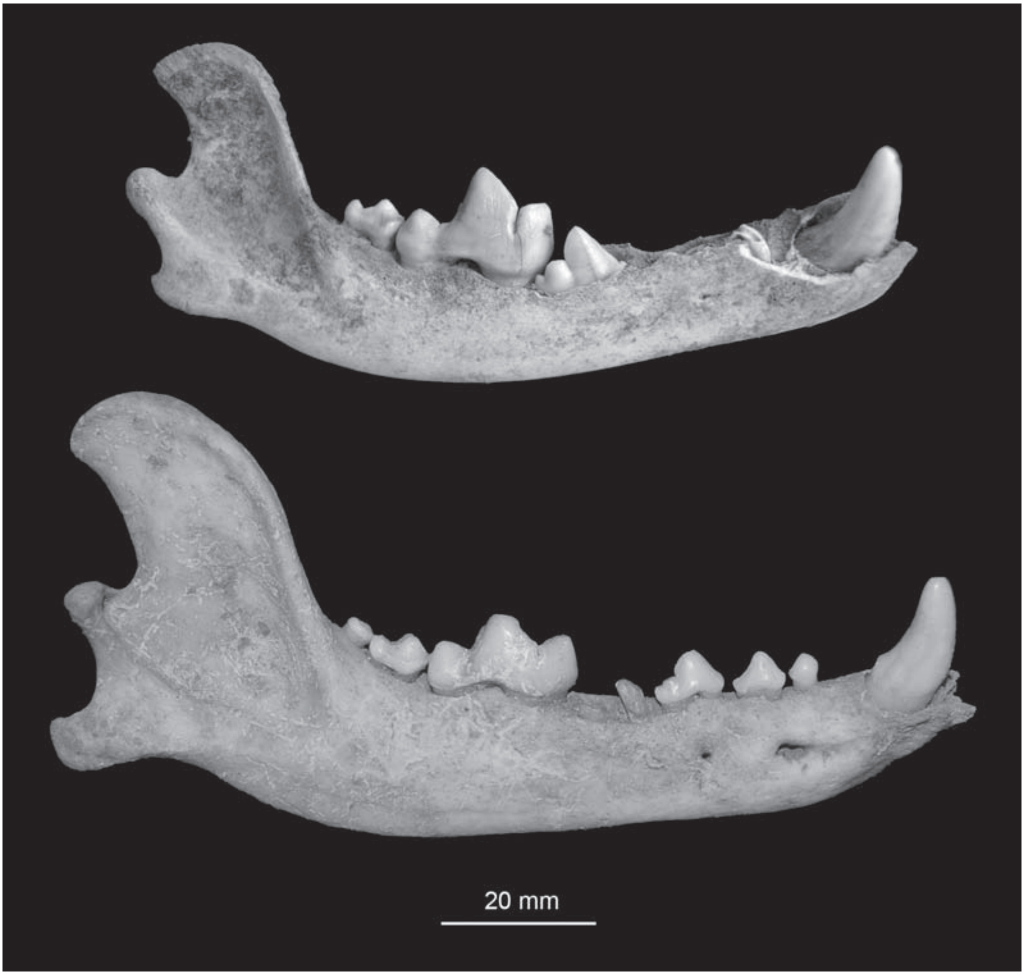

Figure 4.3. Parodontal disease of P_4 in dog mandibles (buccal aspect): incorrect angulation (top) and broken roots (bottom).

The smallest dog, which presented osteoarthritis, was identified by five remains only: the right scapula, humerus and femur as well as the fragmented mandible and pelvis. In contrast to other dog skeletal parts in the sample, these bones were darker, which – in addition to the metrical differences – made their separation easier. A slight exostosis was identified on the lateral condyle of the humerus presenting a lipping-type deformation of the bone.

The single appendicular bone from Pit G11/L29 showing a pathological condition is a proximal phalanx from an adult cattle. The lipping of the distal articular surface resulting from the formation of new bone tissue on its periphery, caused broadening of the distal articular end.

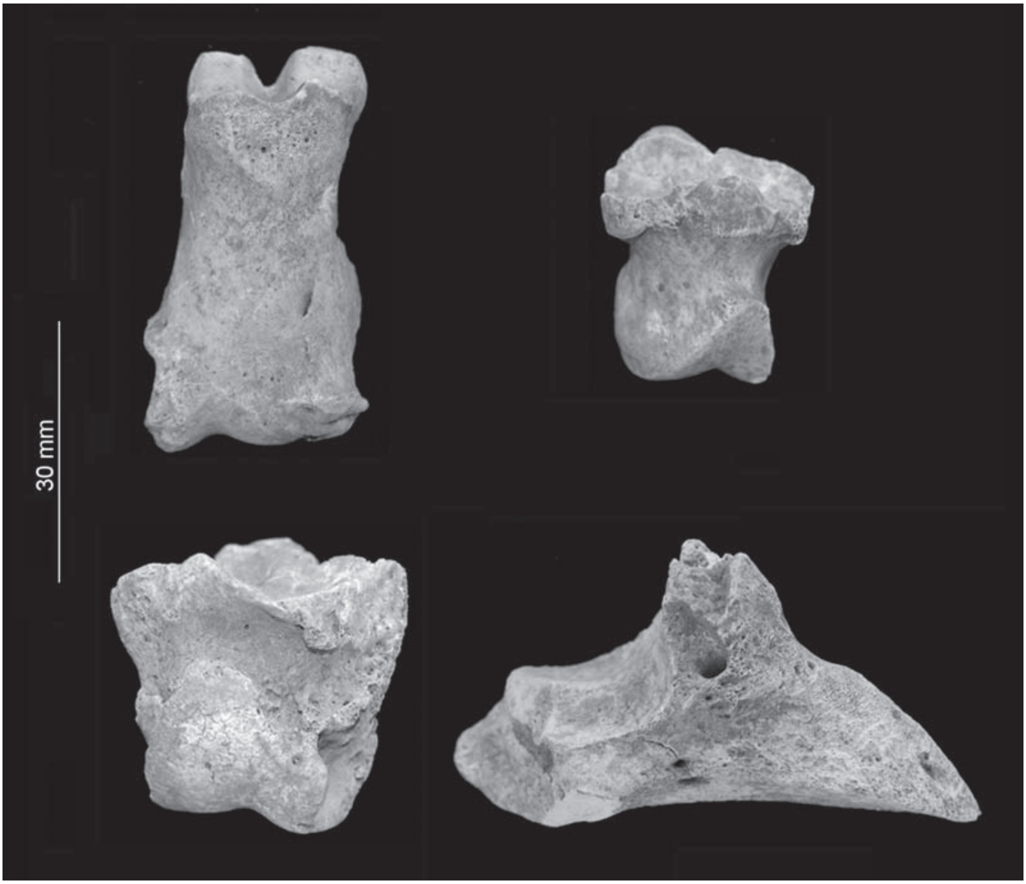

Figure 4.4. Exostoses on cattle phalanges. Top row: proximal and medial phalanges (anterior aspect); bottom row: medial (anterior aspect) and distal phalanges (medial aspect).

The same condition was identified on a number of cattle phalanges in Sample 148–167, Pit M37. Two first phalanges, three second phalanges and a third phalanx showed lipping and various extents of exostoses (Figure 4.4, phalanges). This form of exostosis is named "ring bone", a condition divided into high ring bone, affecting the first, and low ring bone that affects the second interphalangeal joint (Baker and Brothwell 1980, 120, fig. 12).

Incidents of arthropathies in the axial skeleton of cattle from Pit G11/L29 comprise exostoses on the cranial corpus area of a juvenile first rib, and an irregularly enlarged articular facet of the tubercle of a subadult or adult rib from the central-caudal area of the thorax (Figure 4.5). The alterations found in other species concern vertebrae with exostoses and irregular enlargements of the intervertebral joints. They were found in an articulated segment of the thoracic and lumbar spine from an adult caprine, and in three isolated thoracic vertebrae from an equid.

Figure 4.5. Ribs of cattle with arthropathies. Left: inv. no. 1231 (caudal aspect); right: inv. no. 1187 (cranial aspect).

4.3.3 Traumatic lesions

In addition to the remains of the aforementioned three adult dogs, the almost complete skeleton of a young dog was also identified in Sample 236–263 from Pit M37. According to the development of its dentition (Schmid 1972, 77, tab. X) and the ossification of its postcranial bones (Chaix and Méniel 2001), this individual was about five months old at death. The left radius and ulna displayed the traces of a healed greenstick fracture (Figure 4.6). This kind of trauma is typical of non-adult skeletal parts, where the bone bends rather than breaks (Lovell 1997, 143; Bartosiewicz 2013, 47, fig. 29). In spite of the healed wound the young animal died (or was killed). Traces of (other?) human interaction could not be identified on the rest of the skeletal parts of this dog.

Healed traumas on cattle ribs from Pit G11/L29 form the largest group among the pathological lesions from Carnuntum–Mühläcker. Fractures generally occurred transversally to the dorso-ventral direction of the bodies, in a medio-lateral direction. This is in accordance with the mechanical properties of rib bodies which are shaped like flat, curved boards. All lesions can be classified as simple fractures and appear as swellings on the bodies. In nine specimens, fractures were easily diagnosed by the presence of callus formation and/or dislocations along the length of ribs. Compared to the original curvature, the area of the fracture bulges laterally and the ventral segment is bent inward. When viewed from the narrow sides, the fracture often appears like a kink. There is only one specimen (inv. no. 1539) where the fractured area bulges toward the medial side. Only the more heavily affected specimens (inv. nos. 1103 and 1237) correspond to the fractured cattle rib depicted in Groot (2008, figs 6.2–6.3). In this latter case, the callus is irregular, its surface very rough on the lateral side and the fracture line still clearly visible. At Carnuntum, callus formation tends to be smooth both on the medial (pleural) and lateral (external) sides, and the fracture lines can mostly be recognized by the distribution of callus only (Figure 4.7).

Five more rib fragments exhibit bulges or exostoses on their bodies. These pathologies were interpreted as resulting from fractures healed for some considerable time in the animal's past. Probably the transverse process of a lumbar vertebra, the only pathological cattle vertebra found in G11/L29, exhibits a similar lesion. A list of the rib specimens with definite and probable fractures is given in Table 4.2. The following relevant properties of the sample are briefly reviewed here:

Body side: The right side is dominant among the definite fractures (right: six-seven, left: two); the proportions are more balanced if the uncertain cases are included.

Estimated age: Among the clear cases, six specimens were classified as adult or subadult; three fragments are from older juvenile/immature or younger subadult animals; the doubtful specimens also mainly belong to the (sub)adult class. Age was estimated by bone texture and size, because none of the specimens retained the complete articulation area.

Figure 4.6. Healed greenstick fracture of the radius and ulna from a young dog (lateral aspect).

Anatomical position: This parameter was determined in three sections of the rib cage by the number of ribs and the certainty of observation. Definite cases were best represented in the caudal area of the thorax. A single specimen could be assigned to a cranial position (ribs no. 2-4), two near the middle (ribs no. 8-10) while six were caudally located (ribs no. 11-13).

Five probable cases showed a slightly different distribution. Again, only a single specimen originated from the cranial section (rib nos 2–4), two from the middle (rib nos 8–10), but only a single case was caudally located (rib nos 11–13). These values are summarised in Table 4.3.

Position of fractures: Six of the certain fractures were found in the lower half of the bodies of ribs. The remaining positions are from the centre or the upper area. The uncertain lesions are from the middle or upper parts.

Degree of dislocation: Among the definite specimens, the rupture in the original curvature was found to be slight in five cases and serious in four specimens. The remaining ribs exhibit slight or no discernible dislocations.

Butchery marks: All but one specimen were chopped through on their proximal or distal ends.

Figure 4.7. Ribs of cattle with healed fractures. From left: inv. nos. 1237, 1268, 1103, 1195, 1232, sample 1; top – dorsal, bottom: ventral (except in sample 1) (medial aspect); chop-marks on dorsal or ventral ends.

4.3.4 Other types of lesions

A few fragments of cattle ribs from G11/L29 show thin deposits of porotic or cancellous tissue on parts of their surfaces. These pathologies may be linked to inflammatory or infectious diseases, *e.g*. tuberculosis (Bartosiewicz 2013, 97–103).

4.3.5 Inflammatory diseases

Sample 123–137 from Pit M37 contained remains from at least three equid skeletons. According to the degree of ossification of the epiphyses, they belonged to two adults and a juvenile (about one year old) individual. One of the adult horses yielded a complete metatarsus III that indicated a withers height of 132.9 cm for this specimen (Vitt 1952). The fistula noted on the lateral side of this metatarsus indicated the individual had an inflammatory disease of the bone which may have easily been caused by an untreated wound.

4.3.6 Inherited disorders

Oligodonty was identified in cattle. Sample 1479 from Pit G11/L29 contained a total of 214 bones of new born to adult cattle. The first premolar seemed to have been missing

Table 4.2. Cattle ribs with healed fractures from Pit G11/L29.

Inv. No.	*Length (mm)*	*Side*	*Certainty of observation*	*Est. age*	*Position, rib no.*	*Position of fracture*	*Degree of dislocation*	*Butchery marks*
1103	84	?dext.	definite	subadult	8–10	distal half	heavy	dorsal medial chop
1188	118	dext.	definite	adult	11–13	distal half	slight	none
1195	118	dext.	definite	subadult	11–13	proximal part	slight	ventral medial chop
1232	75	dext.	definite	elder juvenile	11–13	distal half	slight	ventral medial chop
1237	97	sin.	definite	elder juvenile	2–4	distal half	heavy	dorsal medial chop
1268	130	sin.	definite	immature	11–13	middle	heavy	ventra l medial chop
1539	135	dext.	definite	subadult	8–10	proximal part	slight	ventral lateral chop
sample 1	101	dext.	definite	adult	11–13	distal half	slight	dorsal medial chop
sample 1	70	dext.	definite	subadult	11–13	distal half	heavy	dorsal+ ventral lateral chop
1216	77	dext.	probable	adult	2–4	middle	none	dorsal medial chop
1243	131	dext.	probable	subadult	8–10	proximal part	none	ventral medial chop
sample 3	95	sin.	probable	adult	8–10	proximal part	slight	ventral medial chop
sample 3	126	sin.	probable	subadult	11–13	middle	slight	dorsal medial chop
sample 7	120	sin.	probable	immature	8–10	middle	none	ventral medial chop

Table 4.3. The anatomical position of lesions by the certainty of observation.

Section of rib cage:	*Ribs nos 2–4*	*Ribs nos 8–10*	*Ribs nos 11–13*	*Total*
definite cases	1	2	6	9
probable cases	1	3	1	5
	2	5	7	14

for genetic reasons from the right mandible of a subadult individual. The frequency of oligodonty in cattle mandibles was noted both in European and North American assemblages by a number of specialists. The absence of P_2 teeth in cattle mandibles was especially high in the medieval assemblage from Haithabu, Germany. Oligodonty is conventionally linked to advanced domestication. Domestication usually meant a preference for docile individuals of low metabolic rates, perpetuating inherited thyroid hormone deficiency, a possible factor causing a shortened facial skull compared to that of the wild ancestor although the condition was also recorded in wild animals (Bartosiewicz 2013, 194–197).

4.4 Discussion

Irregular tooth wear is typical of herbivores. Reasons for it include the congenital absence of teeth, premature loss of teeth, trauma and partial destruction of teeth (Baker and Brothwell 1980, 147–149, fig. 8; Bartosiewicz 2013, 173–176). This symptom was also found on two cattle teeth from the Roman village (2nd century AD to the second half of the 3rd century AD) unearthed at Balatonlelle–Kenderföld in Hungary. In addition, the fracture on the femur of a half-year-old dog, which healed with a serious dislocation, as well as the compound fracture of the radius and ulna from another individual were identified in the latter assemblage (Daróczi-Szabó 2008, 58–60, figs 8.3–8.4). A healed greenstick fracture was also observed on the femur of a young dog from the Sarmatian site of Debrecen–Bethlen utca in Eastern Hungary (Bartosiewicz 2013, 47, fig. 29).

A number of bone fractures from a total of four species were also studied in two assemblages from the Roman Period rural site of Tiel-Passewaaij in the Netherlands. Most of them (12 of 19) belonged to dogs, but there were also three fractured specimens (a mandible and two ribs) from cattle. The high proportion of bones exhibiting healed fractures was thought to be the result of maltreatment by humans or kicks from other large animals (Groot 2008). Ring bone, the exostosis affecting the interphalangeal joints, is thought to be due to concussion from overstrain or old age, and nearly always causes lameness (Baker and Brothwell 1980, 120–121, fig. 12; Bartosiewicz 2013, 126–127, fig. 105). It was observed on a rather great number of draught cattle, especially oxen. Pathological phenomena were more abundant in the thoracic extremities than in the pelvic extremities (Bartosiewicz *et al*. 1997, 44–62, tab. 8, figs 30–40). Similar symptoms also occurred on cattle phalanges from the aforementioned Roman period site of Balatonlelle–Kenderföld in Hungary (Daróczi-Szabó 2008, 59, figs. 8.7–8.8).

The arthropathies found in the axial skeleton of ungulates from Pit G11/L29 may be partly related to the advanced age of the animals (vertebrae of equids and caprines). On cattle ribs they represent a very rare phenomenon which is difficult to interpret.

The high number of healed fractures of cattle ribs from Pit G11/L29 is not surprising. According to a summary based on 335 healed bone fractures from 109 Eurasian sites which includes common mammalian taxa, ribs are the most commonly represented group (Bartosiewicz 2013, 60–63). Since ribs are not weight-bearing elements and are held rigidly in place, they stand a good chance of recovery (Groot 2008, 42), even in large

ungulates where limb fractures often prove fatal. Thus, among the large ungulates in the comparative sample, rib fractures occurred twice as much as expected (Bartosiewcz 2013, tab. 4).

The composition of the characters listed in Table 4.2 requires some comment. The preponderance of the right side among the definite fractures is most likely due to small sample size. The age distribution is in concordance with the general pattern, where elder juveniles, subadults and younger adults prevail. The trends concerning the anatomical position of the fractured ribs, and the placements of the lesions along the bodies, however, deserve attention. Most of the fractured ribs are from the caudal half of the thorax. Among the definite cases, even the terminal area (ribs 11–13) is, by far, the most heavily affected. In this group, the locations of the fracture lines are situated in the lower half or in the centre of the bodies. Conceivably, these areas of the thorax are the ones most exposed to pressure or force from outside. This does not necessarily imply direct inter-specific aggression or human maltreatment in the strict sense. For instance, these injuries may have been inflicted when herds were driven through narrow gateways. Rib fractures are even a common feature in present-day cattle solely designated for slaughter, but their preferential distribution along the thorax in the Carnuntum specimens appears somewhat different (Paton 2014).

Apart from Tiel-Passewaaij where two out of three fractures of cattle bones are on ribs (Groot 2008), the dominance of rib fractures among the traumatic lesions in cattle has been reported from other Roman sites as well. For instance, at the villa of Reinheim (Saarland/Germany), a healed fracture of a rib represents the only case, although other types of pathologies apart from traumatic lesions were more common in this species (Schoon 2006). This conforms to the statement by Peters (1998, 69–71) that traumatic lesions generally are in third place after dental pathologies and arthropathies, including stress markers, in Roman cattle. Similarly, in the vicus of Vitudurum (Switzerland; Morel 1991), among 264 cattle remains identified as pathological, traumatic lesions were exclusively present on ribs (eight cases) and horn cores (two cases). However, these rib fractures do not correspond to the picture observed in Carnuntum but rather represent examples of incomplete healing: callus developed around the broken ends, which would eventually form a false joint with their respective counterparts (see Bartosiewicz 2013, 49). The incidence of this type of lesion appears rather high, since 640 fragments of cattle ribs were identified altogether. Such areas of disunited callus without bridging of the fracture were also observed in ten fragments of cattle ribs from the vicus of Rainau-Buch (Baden-Württemberg/Germany; Gulde 1985). At this site, which yielded over 2500 fragments of cattle ribs, only two specimens with healed fractures were found.

It is certainly noteworthy that these pseudarthroses in fractured bodies of cattle ribs are completely absent in the sample from pit G11/L29. They are, however, known through anecdotal evidence from other areas in Carnuntum, *e.g.* from the civil town. Their occurrence may generally be linked to the slaughter and consumption of elderly (draught) cattle. Possibly, a fusion of the segments was hindered by excessive movement during healing, or by the advanced age of the animals. The presence of this age group, or of draught animals, in the assemblage from the fill of Pit G11/L29 can be largely excluded.

4.5 Pathological lesions and butchery marks

All but one of the cattle ribs with definite or probable healed fractures from Pit G11/L29 have butchery marks on them. The bodies of ribs were chopped through on their upper or lower ends, or both. The same holds true for one of the ribs with arthropathies. This specimen was chopped through its head. The percentage of specimens with butchery marks is, therefore, even higher than in the total assemblage of cattle ribs from Pit G11/L29. This may be due to the fact that longer and more completely preserved fragments are also more likely to exhibit both pathological lesions and anthropogenic marks. The average length of rib fragments with pathologies is 106 mm, while in the sample as a whole, it is 96 mm. Obviously, the use of the meat parts was not hindered by the presence of healed fractures on the ribs. It is, of course, uncertain if the healed fractures were visible to the butcher at all, although the areas of callus formation were generally not touched by the blade of the cleaver. The same holds true for a rib fragment with a healed fracture and extended callus depicted in Groot (2008, figs. 6.2–6.3), which was apparently chopped through at both ends. Presumably, some swelling of the soft parts may have been noticeable in these cases. The possible connection between butchery marks and pathological lesions appears to be a worthwhile topic for future research.

4.6 Conclusions

Several remains showing pathological conditions on skeletal elements from the cranial and appendicular skeleton were identified in Pit M37 and Pit G11/L29. Although the bone assemblage found in the latter pit was larger, it mostly contained the remains of young individuals representing food served for feasts within the sanctuary grounds. Based on the generally younger age of the animals, fewer pathological conditions would be expected to occur.

Pit M37, situated outside of the sanctuary, displayed more mixed characteristics: the remains of pig, equid and dog occurred more commonly than in assemblages from the sanctuary. The age distribution of animals slaughtered for meat is also more variable. The frequency of pathological lesions may therefore be attributed to the faunal composition of the assemblage on the one hand, and to the greater presence of old animals on the other. Because the axial skeleton has only been studied for parts of the material from Pit G11/L29 no comparisons can yet be made with the faunal material from Pit M37. In G11/L29, healed fractures on the bodies of cattle ribs (9–14 specimens altogether) outnumber all other types of lesions. These injuries are concentrated in the caudal part of the thorax and may have been inflicted when the animals were rounded up or driven through narrow spaces. All fractures were completely healed and represented no obstacle for the subsequent butchery and consumption of the attached meaty parts. The dominance of fractures in this cattle sample is compatible with the idea that a highly selected population was chosen for slaughter at the sanctuary.

In contrast, many other collections of Roman cattle bones, in Switzerland, Austria and Hungary at least, display the prevalence of quite different types of pathologies, notably arthropathies and markers of stress. The differences even concern the types of trauma observed in ribs, because pseudarthroses of body segments which are common

in faunal materials from other sites, are absent on the bones from Pit G11/L29. It seems reasonable to think that archaeological cattle populations could be characterised and compared by the inventory of their skeletal pathologies as well.

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5. Animal Health in Justiniana Prima (Caričin Grad): Preliminary Results

Nemanja Marković, Oliver Stevanović, Nikola Krstić, Darko Marinković, Maciej Janeczek, Aleksander Chrószcz and Vujadin Ivanišević

Caričin Grad is located in southern Serbia, on the eastern slopes of the Radan Mountain, 30 km southwest of Leskovac. The remains of Caričin Grad are associated with the important Early Byzantine city *Justiniana Prima*, founded *ex nihilo* in the AD 530s by the emperor Justinian I (527– 565), in order to perpetuate his birthplace. Situated in a rural area in the western part of the province of Dacia Mediterranea, the city presents a unique example of late urbanisation in the northern provinces of Illyricum. Since it lasted for a very short time – only 80 years – and the area has remained uninhabited until today, the site has yielded well-preserved monuments and remains of material culture. Animal bones showing pathological changes come from three locations in the city: the complex of the south-eastern corner tower of the Lower town, the intramural housing in the Lower town and the intramural housing in the Upper town. The main part of the material originated from occupation layers dated to the second half of the 6th century. This paper presents the analysis of animal remains with pathological changes from Caričin Grad, discussing their significance for economy and social status in Justinia Prima.

5.1 Introduction

Caričin Grad, situated 30 km south-west of Leskovac and 8 km north-west of Lebane in southern Serbia, was founded in the second quarter of the 6th century. The remains of the city were identified as Justiniana Prima, the polis that, according to *Novella* 11, Emperor Justinian I (527–565) built to be the seat of an archbishop and the Praetorian prefect of Illyricum (*Novellae*, 94).

The emergence of the new polis represents a particular phenomenon explained by the Emperor's wish to honour his place of birth, as well as by a need to strengthen the interior of the diocese of Dacia (Kondić and Popović 1977, 367–371; Bavant 2007, 337–374; Zanini 2003, 196–223; Ivanišević 2016, 109–110). The city was built in a strategic location, with well-developed fortifications, water supply systems, numerous churches, administrative and public buildings, broad porticos, plazas and housing quarters (Procopius, *De Aedificiis* IV.i.21–25). The city was struck by economic decline during the second half of the 6th century. This can be well documented through

changes in architecture and other findings (Ivanišević and Stamenković 2013). Archaeologists have conducted excavations at Caričin Grad for more than a century. In the last two decades, research has focused on two important sections of the city: the intramural housing and fortification of the Lower town and the northern slope of the Upper town, a part between the northern wall of the Acropolis and the northern rampart of the Upper town.

This paper describes animal health in the city, with special focus on possible differences in the prevalence and type of pathological changes between samples from the Upper and Lower town at the time of economic decline. The analysis of animal remains at Caričin Grad is still in progress; conclusions, therefore, will be based on preliminary results.

5.2 Archaeological context

New analysis of space allocation in Caričin Grad (*Justiniana Prima*) reveals the importance of housing in different areas of the city in contrast to the old opinions of the primarily administrative, public and ecclesiastical organisation of the urban core (Ivanišević 2016, 114–119, fig. 4).

The first residential quarter was excavated in the south-western part of the Lower town from 1981 to 2008 (Figure 5.1b). The long-standing excavations, with a break between 1991 and 1996, revealed organised housing with buildings spreading in two rows: the first aligned with the western portico of the south street of the Lower town, and the second in the free space along the western rampart. We can distinguish two basic types of houses; those with a developed organisation of space and an atrium, and simple houses with a single principal space and a small additional room. The ground floor of all the houses was erected of stone, bonded with clay – *opus craticium*, while the upper storey, if there was one, was made of adobe, or timber and cob. The existence of a third type of house is problematic, as the structures made of timber and cob were poorly preserved and are thus hard to define. They may also have been storage spaces, just like the few structures with walls in the middle of the courts (Ivanišević 2010).

The residential quarter was already erected in the time of Justinian I judging by numerous finds of coins. It lasted until the end of human habitation of the city in the first decades of the 7th century as testified by a find of a hexagram of Heraclius struck from 615 to 625. The majority of finds, more than 10,000 items, excluding the ceramics and the glass, were discovered in the courts around the houses, implying regular housekeeping and disposal of garbage in the courts. No deposit pits occured in the residential quarter. Other finds are related to everyday life, mainly housing, household equipment and personal items. Particularly noteworthy are findings related to economic activities, primarily agriculture and livestock breeding, as well as evidence of numerous trades and crafts; this includes the processing of wood, metal, bone and antler, textiles, leather, glass, ceramics, stone, and other crafts. The findings of numerous scales and weights clearly indicate the presence of money-changers. The finds of medical instruments were also numerous.

Figure 5.1. Plan of Caričin Grad: a) the intramural housing in the Upper Town; b) the intramural housing in the Lower Town; c) the complex of the South-Eastern corner tower of the Lower town.

Based on the organisation of space, houses and the finds, the residential quarter in the south-west part of the Lower town was likely inhabited by a middle class of civil servants, soldiers, artisans and merchants (Ivanišević 2010).

By the end of the field work in the Lower town, a new sector was exposed: the complex of the south-eastern corner tower (Figure 5.1c). The main aim of these investigations was the excavation of the corner tower in order to define the plan of these important defence facilities. During the course of the field work, researchers excavated a part of the settlement in the interior of the city, along with few structures outside the city in the suburb.

The main result of this field research was the definition of the plan of the tower, and establishment of the existence of important earthworks around the tower, which allowed for the separation of three strata. The first stratum was associated with a workshop, possibly for manufacturing glass or vitreous mass, dated to the reign of Justinian I.

Judging by the coins recovered, after the demolition of the kilns, the entire space was levelled with rubble and earth in the first years of Justin II. The third and last stratum containing a row of structures dated to the second half of the 6th century. Excavations in the area of the south-eastern tower permitted for more accurately dividing the portable archaeological material in two main chronological periods: the reign of Justinian I and the period from Justin II to the end human habitation (Ivanišević and Stamenković 2010).

The third area investigated in Caričin Grad in the last decades comprised the northern slopes of the Upper town and parts of the ramparts and towers of the Acropolis (Figure 5.1a). The excavations of this area are still in progress, but based on preliminary results we can distinguish two zones in this part of the city: one with public buildings in the eastern part, with a *horreum* and several unidentified structures, built in *opus mixtum*, and the second with a residential quarter and storage facilities, built of stone and bonded with clay (Ivanišević *et al*. 2016). The layers, within this sector, can be mainly dated at the second half of the 6th century; however, the structures were erected in the time of Justinian I. The only layers that can be dated at this earliest phase of the city's life were investigated in the vestibule of the *horreum*.

The excavations of the towers in the Acropolis were carried out as part of the program aimed at restoring the fortifications. Despite the disturbed layers, due to previous investigations in some of the towers, especially C, D and G, well-preserved layers reflect levelling in the interior of the towers. These levels are difficult to date precisely in the absence of coin finds.

5.3 Materials and methods

Animal bones showing abnormal changes come from three locations in the city: the intramural housing in the Upper town, the intramural housing in the Lower town and the complex of the south-eastern corner tower of the Lower town, and most of the material is dated to the second half of the 6th century and the first decade of the 7th century. Material from the south-eastern corner tower was previously published (Marković *et al*. 2014a). Of the total of mammalian specimens collected (22,246), 11,807 fragments could be identified to at least genus level. The remains of 31 species were identified in the faunal assemblage from Caričin Grad. The domestic species include sheep (*Ovis aries*), goat (*Capra hircus*), cattle (*Bos taurus*), pig (*Sus domesticus*), horse (*Equus caballus*), donkey (*Equus asinus*), mule (*Equus caballus* x *Equus asinus*), camel (*Camelus* sp.), dog (*Canis familiaris*), cat (*Felis catus*), hen (*Gallus domesticus*), duck (*Anas domesticus*) and goose (*Anser domesticus*) while the wild species comprised red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild pig (*Sus scrofa*), hare (*Lepus europeus*), fox (*Vulpes vulpes*), brown bear (*Ursus arctos*), beaver (*Castor fiber*), falcon (*Falco* sp.), carp (*Cyprinus carpio*), bream (*Abramis brama*), crucian carp (*Carassius carassius*), barbel (*Barbus barbus*), pike (*Esox lucius*), catfish (*Silurus glanis*), beluga sturgeon (*Huso huso*), sterlet (*Acipenser ruthenus*), stellate sturgeon (*Acipenser stellatus*) and one fish species from the family *Sebastidae*. Domestic animals outnumber game (comprising over 90% of NISP), and evidently provided an important and reliable meat supply. Based on the number of identified specimens (NISP), caprines (sheep and goat) are the most

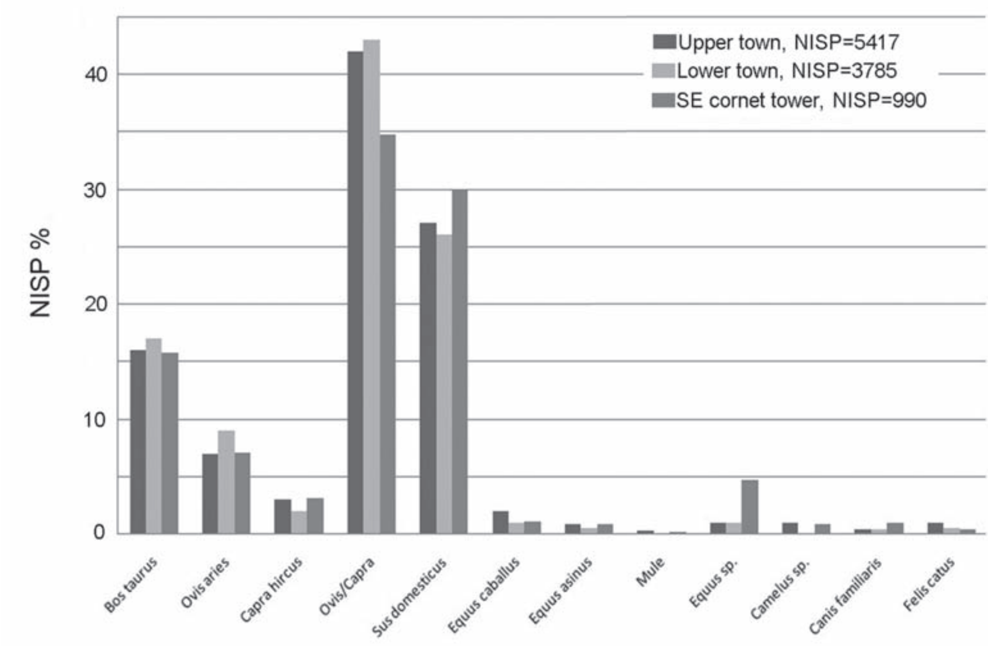

Figure 5.2. Relative frequencies of domestic taxa.

commonly encountered taxa in all three faunal assemblages, followed by domestic pig, cattle, domestic hen and wild pig (Figure 5.2). Other mammalian taxa altogether comprise less than 10% of NISP. Wild pig is the best represented game species; red deer, roe deer and hare were also hunted.

Out of the 11,807 identifiable specimens, anomalous bone structures were found in 96 (0.81%) cases. All bones showing abnormal changes were divided in two groups: those displaying congenital morphological variations and those deformed by acquired pathological changes. The latter group of remains showing acquired pathological changes can be divided into five subgroups, those with:

- dental pathology,
- degenerative bone alterations,
- bone inflammation and infection,
- traumatic alterations (trauma) and
- pathological lesions of unknown origins.

The diagnosis of pathological changes was made on the basis of literary references widely used in palaeopathology (Baker and Brothwell 1980; Bartosiewicz 2013) and veterinary medicine (Thompson 2007). Representative examples of bones displaying pathological changes presented in this paper were analysed radiographically. The specimens were first inspected macroscopically, followed by X-ray analyses using a

Siemens Selenos 400 (55kV, 16mAs) X-ray apparatus. Computed tomography (CT) imaging of the specimen was performed with the help of a Siemens Somatom AR. STAR scanner (slice thickness 2 mm and 3 mm, 110 kV, 63 mAs).

5.4 Results

Pathological lesions were first classified into congenital and acquired. Out of 96 bones showing various anomalies, 57 (60%) come from the Upper town, 30 (31%) from the Lower town and 9 (9%) from the south-eastern corner tower. According to gross (macroscopic) bone observation and radiological analysis, different types of bone alterations were attributable to multiple aetiologies. The only type of congenital morphological variation detected was an accessory mental foramen on one sheep mandible from the Upper town and on two from the Lower town.

Bones displaying pathological changes originated from domestic animals: cattle, horse, donkey, camel, sheep/goat, pig and cat. In the bone assemblage from the three locations in Caričin Grad, the most prevalent and prominent pathological changes were recorded on bones which originated from working animals (cattle, equids and camels). The most commonly encountered changes in cattle were traumatic lesions in all three samples (Figure 5.3d). Only degenerative bone alterations and traumatic symptoms were observed in horse bones (Figure 5.3b–d). Pathological changes were identified in only four (7.6%) donkey bones from 52, with the following remarks: exostoses on the first phalanx and ossification of the interosseous ligament attachments of the metatarsal bone from the Lower town, abnormal tooth wear and exostoses on the first phalanx from the south-eastern corner tower (Figure 5.4d). On the other hand, in the case of small ruminants and pigs the most prevalent changes were bone inflammation and infection, dental anomalies, and traumatic alterations in the case of pig (Figure 5.3a, c, d).

Bone deformations in working animals (cattle, equids and camels) appeared primarily on front and hind limb elements – phalanges, metacarpal and metatarsal bones. These pathological changes can be described as local bone overgrowth (bone spurs) – exostoses, in most cases developing as a consequence of local (traumatic) periostitis. In equids, exostoses are frequently seen on the ligament attachments of phalanges, also referred to as enthesiopathies. Macroscopic examination of the first phalanx of horse from the Upper town revealed ossifying periosteal proliferations on the bone surface. They were manifested in the form of osteophytes localised in places of ligament attachments – enthesiophytes (Figure 5.4e). Results of X-ray analysis and 3 mm-thick CT scan slices of transversal sections revealed increased transparency of the osseous tissue with rough, knot-like spongy bone tissue, with marked and widened *Haversian* and *Volkmann canals*. The cortical bone was thinned and discontinued and compact bones have a woolly, flaky and spongy appearance. Ossifying periosteal proliferations in the form of osteophytes were noted on the bone surface. Other, frequent pathological changes in equids, especially from the Upper town, were ossifications of interosseus ligaments of the metapodial bones (*desmoiditis ossificans ligamenti interossei*). Two camel second phalanges developed exostoses. One of these bones was found in

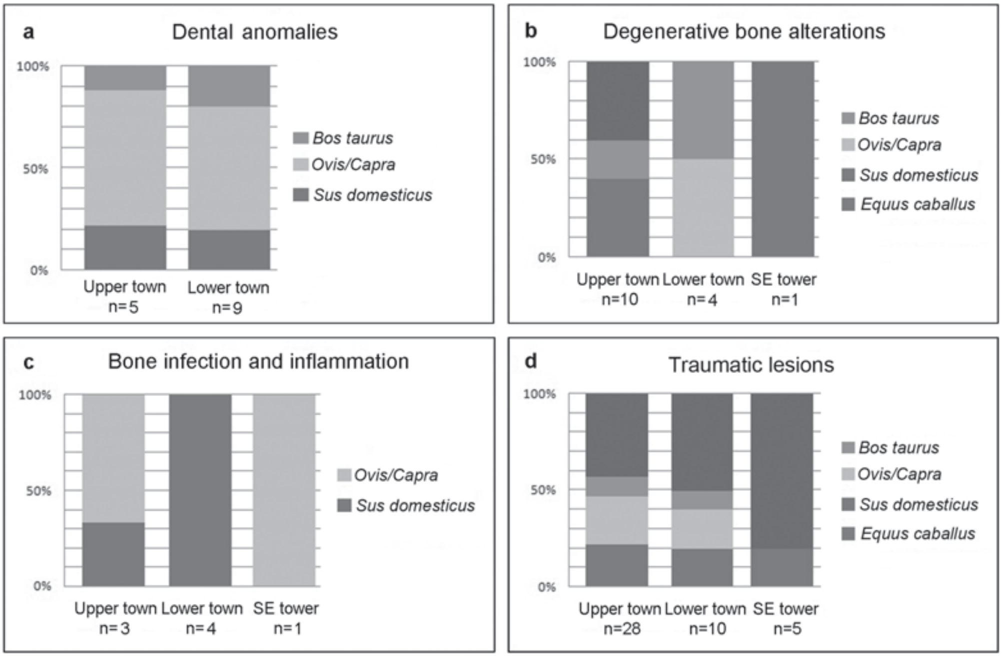

Figure 5.3. Relative frequencies of pathological changes from Caričin Grad.

the Upper town and the other was recovered from the south-eastern corner tower, dated to the time of Justinian I (527–565; Marković 2013). Gross examination of the second phalanx of the camel revealed ossifying hypertrophic exostoses. This bilaterally osteogenic hyperplasia led to the formation of large proliferations which increased the diameter of the bone (Figure 5.4b, c).

Signs of ankylosis and articular surface deformities can be attributed to degenerative joint diseases. These changes are particularly frequent in the distal articular surfaces of hind limb bones of horse and cattle. On the axial skeleton of the horse remains from tower D of the Acropolis, small osteophytes were evident on the bodies of some lumbar and thoracic vertebrae. It seems that these changes are associated with *spondylosis chronica deformans*. Macroscopic examination of a cattle tibia showed periosteal proliferations – osteophytes (*periostitis chronica ossificans*), localised on the tibia cochlea as well as medially and laterally on the malleolus (Figure 5.5a). Results of X-ray analysis and 3 mm-thick CT scan slices of transversal sections of the aforementioned bones showed periosteal proliferations in the form of squamous-like osteophytes (*periostitis chronica ossificans*) localised on the tibial cochlea, as well as medially and laterally on the malleolus. Subperiosteally the bone had a marked hyper dense uneven-shaped zone which fills the whole medullary canal of the distal tibia fragment. This resulted in a melting, thickened, mineralised appearance of the compact bone. Gross analysis of the distally located tarsal bones (fused *os tarsale II et III* and *os centroquartale*), as well as

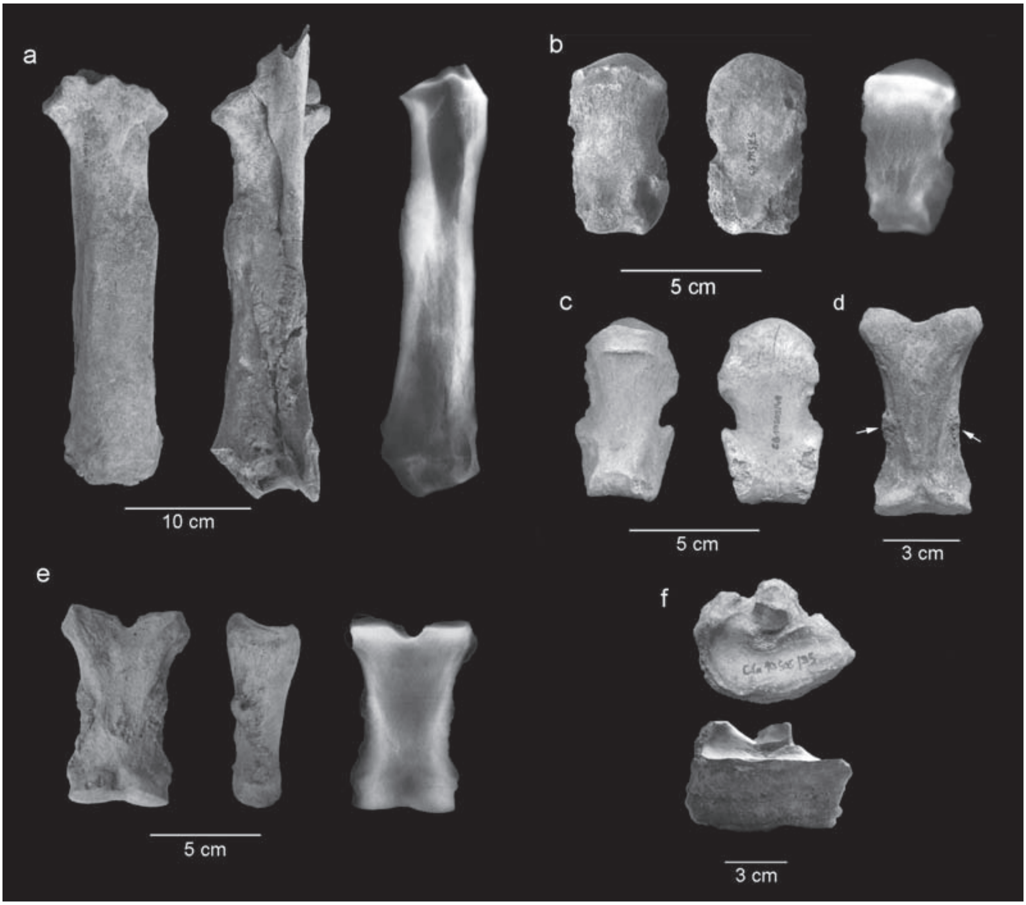

Figure 5.4. Bones showing degenerative alterations: a) cattle radius (Upper town); b) camel second phalanx (Upper town); c) camel second phalanx (SE corner tower); d) donkey first phalanx (SE corner tower); e) horse first phalanx (Upper town); f) fused central and third tarsal bone of horse (SE corner tower).

a proximal metatarsal epiphysis, revealed proliferative destructive changes that were characteristic of chronic deformative inflammation of the affected joint (Figure 5.5b). A marked narrowing of interarticular spaces between corresponding articular surfaces was present. These changes indicate the presence of a chronic degenerative pathological process. X-ray examination and CT scan slices of 3 mm-thick transversal sections of the distal tarsal bone (fused *os tarsale II et III* and *os tarsi centrale et IV*), as well as proximal metatarsal epiphysis, revealed proliferative destructive changes that are characteristic of chronic inflammation in this joint. The narrowing of interarticular spaces between corresponding articular surfaces points to the presence of a degenerative pathological process; the compact bone has a mineralised appearance displaying increased density,

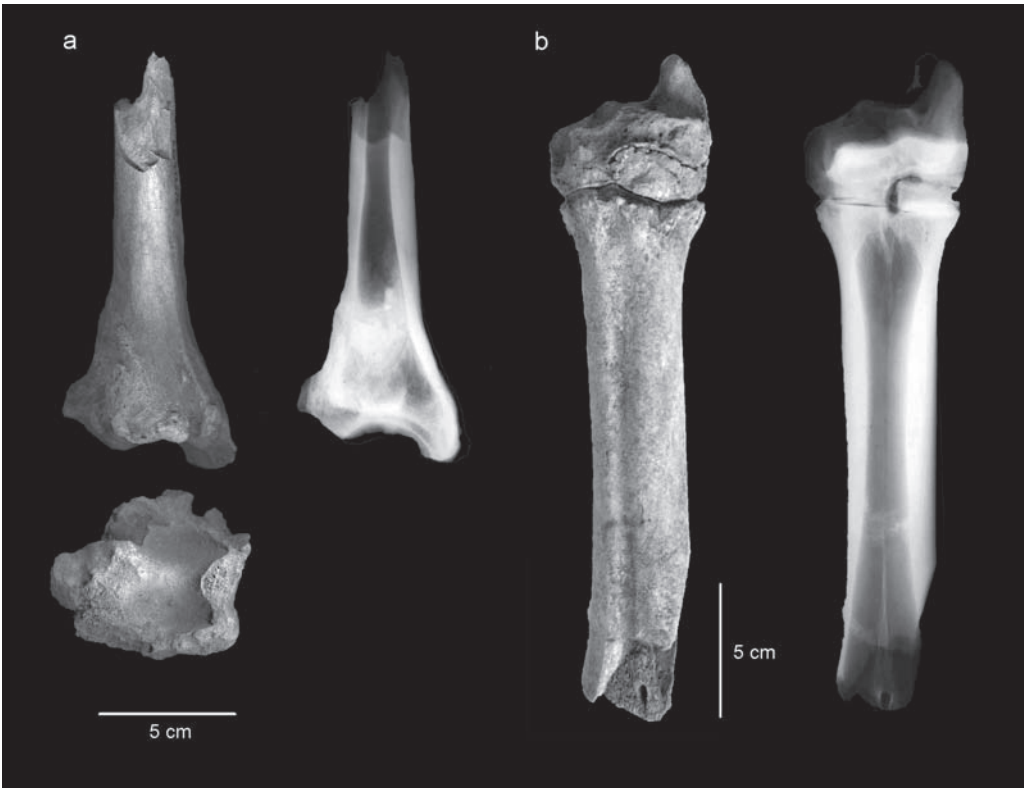

Figure 5.5. Bones damaged by traumatic alterations: a) distal part of cattle tibia (Upper town); b) cattle tarsal joint (Upper town).

and it is thickened, which significantly narrows the spongious bone. Spavin appeared on horse tarsal bones from the south-eastern corner tower (Figure 5.4f).

Representative specimens for bone pathologies of traumatic origin were evident in the form of highly developed calluses on a cattle radius and some pig ribs. Radiological analysis and 2 mm-thick CT scan slices of transversal sections of a cattle radius and ulna showed healed oblique fractures in the proximal diaphysis of the radius, causing a productive periosteal reaction characterised by the formation of large osseous callus; this is a subperiosteal, hyper dense, sclerotic weakly-marginalised zone which stretches from the cortical bone towards the medullary cavity (Figure 5.4a). In the region of transition to the middle diaphysis of the radius, there was complete obliteration of the medullary cavity filled with newly formed endosteal hyperplastic osseous tissue. In addition, a marked reduction of the trabecular, tubular and laminar structures of the spongy bone occurred in this radius, together with the widened mineralised appearance of the compact bone. This geometric change of the bone could be related to abnormal stress trajectories along the axis of the bone: the amount of osseous mass is proportional to the level of mechanic load: the amount of osseous tissue increases

along with the increasing level of mechanical stress. The aforementioned phenomena explain the continuous remodelling observed in the mature bone.

Dental anomalies occurred most frequently in the case of sheep/goat, pig and cattle. They included abnormal tooth wear, periodontal disease, periapical abscess, dental gangrene, *cremor dentium*, and mandibular osteomyelitis (Figure 5.3a). The gross analysis of a caprine mandibula revealed elevations (bulging) of the mandibular body developing a smooth and mildly porous appearance of the outer contour, especially on the lateral side (Figure 5.6a). Using radiological analysis and 2 mm-thick CT scan slices of transversal sections, lytic hipodense regions of different sizes were observed in the spongy bone; trabeculae penetrate the lesion, creating a "soap bubble" appearance. The expansion (elevation) of the bone with a smooth outer contour was observed on the lateral side of the mandibular body. Alveolar septi of the missing tooth above the lesion show signs of dislocation; radiological diagnosis points to odontogenic keratocysts or multilocular ameloblastoma. A gross analysis of a pig mandibula revealed periosteal proliferation on the part of the incisive region and the corpus of the mandibula. The periapical lesion is round, surrounded by a calcified membrane-like structure (pyogenic membrane) with clear margins: all these changes are indicative of periapical abscess (Figure 5.6b).

Other types of bone inflammation and infection were present in the distal parts of pig front and hind limb bones, especially in those from the Lower town (Figure 5.3c). A macroscopic examination of fragments from a pig metacarpus revealed ossifying hypertrophic changes in the form of extensive exostosis. It affected the distal part of the metacarpal bone, first phalanx and proximal sesamoid bone, which led to a complete osseous fusion of the metacarpophalangeal joint (*ankylosis ossea vera*; Figure 5.6c). X-ray examination and 2 mm-thick CT scan slices of transversal sections of this pig metacarpus revealed destruction and periosteal proliferation of the articular surface showing cystic, weakly marginalised subperiosteal lesions. Local, necrotic changes in spongiotic bone which reduce the first level macrostructure, together with the transparent appearance of the centre of the bone characterised by striated contours and large uncalcified spaces were also observed. Lateral calcified prominences could be seen on the articular edges, with an irregular and curved zone of preparation that has multiple single islands of calcification. A gross examination of the second and third metacarpal bones of the pig showed diffuse periosteal proliferations (exostoses), localised in the distal part of the second metacarpal bone (Figure 5.6d). The surface of the affected part of the bone had crack-like bone defects. Results of X-ray analysis and 2 mm-thick CT scan slices of transversal sections of the second and third metacarpal bones of the pig showed amorphous, calcified periosteal proliferation localised in the distal part of the second metacarpal bone with tunnel-like hypodense spaces in the centre, without a notable marginalisation of the bone. The surface of the affected part of the bone had defects and the compact bone developed lesions on the outer side as a consequence of osteoclastic activity. There was proliferation of the mineralised compact bone on the inner side which filled the central part of the bone. The CT scans also revealed hypodensity in the entire medullary cavity without notable architecture in the spongious substance.

The ankylosis of a cat scapulohumeral joint from the Upper town was a special case. The macroscopic observation of this cat shoulder joint indicated solid, continuous ossifying hypertrophic change in the form of a large exostosis on the proximal epiphysis,

Figure 5.6. Bones with inflammation and infection: a) sheep mandibula (Lower town); c) pig mandibula (Upper town); c) fused metacarpophalangeal joint of pig (Lower town); d) pig second and third metacarpal bones with periosteal proliferations – exostoses (Lower town).

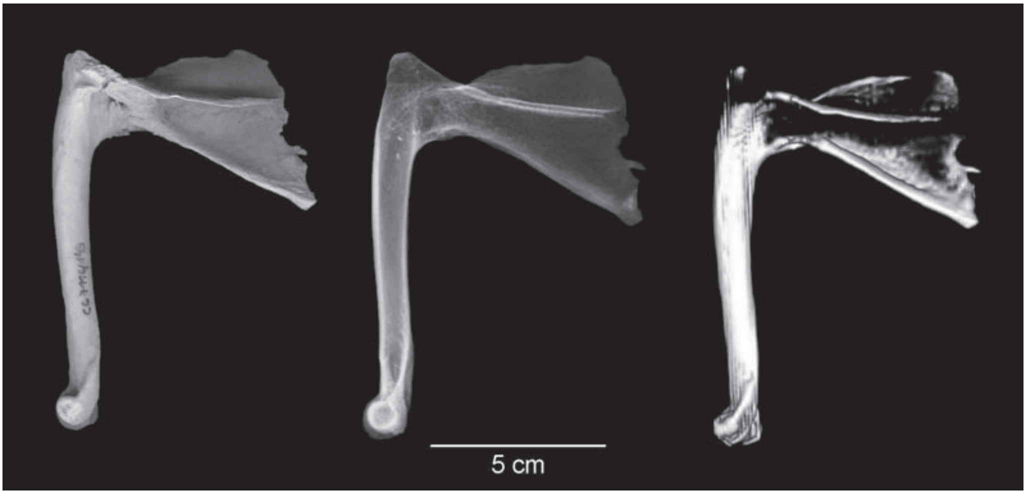

Figure 5.7. Scapulohumeral joint of cat with ankylosis (ankylosis osseavera), X-ray and 3D reconstruction (Upper town).

metaphysis and even diaphysis of the humerus. Exostoses continued over the neck and in the glenoidal cavity of the scapula (Figure 5.7). These ossifying hypertrophic changes led to a complete osseous fusion of the scapulohumeral joint (*ankylosis ossea vera*). Results of the X-ray analysis and 2 mm-thick CT scan slices of transversal sections of the same region showed solid, continuous ossifying hypertrophic appositions on the proximal epiphysis, metaphysis and diaphysis of the humerus, as well as on the neck and in the glenoidal cavity of the scapula. This osseocartilagenous hyperplasia led to the formation of large exostoses which increased the diameter of the bone. Sclerotic changes were present in the spongy bone of the humerus, and the cortical part of the bone appears similar to a compact bone. The characteristic trabecular appearance of the medullar canal of the bone had been lost, and was replaced by condensed spongiosclerotic zones. The fusion of the humeral joint with mineralisation was observed.

In some cases, the causes of pathological changes remained unknown. For example, an unexpected foramen in a cattle acetabulum and an abnormal bending of a pig tibia remained unexplained.

5.5 Discussion

Palaeopathological studies are rare from Early Byzantine archaeological contexts. So far there are two types of published palaeopathological finds from this period. First they form part of a larger archaeozoological monograph, such as material from *Nicopolis ad Istrum* along the right bank of the Danube river in Bulgaria (Beech 2007, 174–176). The second type is represented by individual studies dedicated to diseases of particular species such as those described on Byzantine horse skeletons (Onar *et al*. 2012) and the osteological evidence of Byzantine draft cattle, both from the Theodosius harbour at

Yenikapı, once the centre of the Byzantine Empire in present-day Istanbul, Turkey (Onar *et al*. 2015). This study from Caričin Grad, although preliminary, is the first broader, targeted research of animal disease from an important Early Byzantine site, which includes the complete collection of archaeozoological remains.

The total prevalence of bones diagnosed as affected by pathological changes in the archaeozoological material from Caričin Grad was 0.81%. These results correspond to data in the literature, where the prevalence of pathological lesions ranges from 0.08% to 1.4% in domestic animals (Fabiš 2004; Grimm 2008). Based on classification systems from the palaeopathological literature, all pathological changes were additionally divided into lesions that are not related to work and osteological changes that can be associated with the direct exploitation of animals (Bartosiewicz 2013, Janeczek *et al*. 2014). This classification was applied to cattle, horse, donkey and camel remains, and yielded preliminary insights on the possible differences between the intensity of animal exploitation in the three locations of the city.
Previous studies have investigated the presence of pathological changes and their possible connection with the different patterns of exploitation of working animals (Fabiš 2005; Groot 2005; Johannsen 2005; Telldahl 2005). In the last 30 years of animal palaeopathology numerous studies have demonstrated the pathological aspects of the connection between humans and animals in different time periods, or at least set the archaeological context for the interpretation of pathological phenomena detected on animal bones.

The first major investigations on "modern" animal palaeopathology confirm the hypothesis that certain pathological changes in the axial and appendicular skeleton of large domestic animals can be associated with exploitation by humans. Changes in the metapodial bones as well as phalanges and corresponding joints in cattle can result from local traumatic periostitis and arthritis, which is associated with the use of these animals for traction. However, animals that have not been used for traction may also show a small degree of changes in these bones, usually due to advancing age and the greater bodyweight of mature animals (Baker and Brothwell 1980; Bartosiewicz *et al*. 1997; Johannsen 2006, 38–40). Degenerative joint alterations (arthropathies) are good indicators of animal use and exploitation. In addition, articular depressions as causes of possible ostechondrosis can be seen in some lower limb bones of cattle (Telldahl 2012). Chronic fusions between vertebrae (*spondylosis chronica deformans*) in horses can be associated with a number of factors aside from intensive horse riding. Differential diagnoses include genetic predisposition and aging (Bartosiewicz and Bartosiewicz 2002). Changes in distally located limb bones in horses are a consequence of chronic periosteal irritation and trauma which is evident in sport, military and traction horses (Marković *et al*. 2014b). Although, as in the case of cattle, a small degree of change in these bones may occur in horses that have not been used for working; these osteological symptoms are inseparable from and thus may be the consequence of aging (Bendrey 2007). Degenerative bone lesions and traumatic alterations are the most frequent pathological phenomena on bones in all three locations from Caričin Grad. Yet, pathological deformations potentially associated with working animals are the most frequent in the sample from the Upper town (Figure 5.8). Proliferative and chronic

changes in bones in the form of various types of exostosis are the most frequently encountered. They are evident in large animals such as cattle, horses, donkeys and camels, a trend indicative of intensive draught exploitation in tillage and transport. Large domestic animals, both cattle and equine, played an important role in the economy of the city; they were not only the source of food and raw materials (meat, fat, skin, bones, and mik, especially in the case of cattle), but were also widely used as working animals. According to preliminary results, a higher prevalence of proliferative changes was recorded in the phalanges, and metapodial bones. Also, degenerative changes were frequent to the joints of large domestic animals from the Upper town.

Other pathological changes diagnosed at the settlement of Caričin Grad have already been described in the general literature on animal palaeopathology (Baker and Brothwell 1980; Bartosiewicz 2013); however, congenital morphological variations have rarely been discussed. Three cases of accessory mental foramens in small ruminants were present in the assemblage. Similar changes mentioned by Baker and Brothwell (1980) are significant because it is suspected that additional branches of the mandibular nerve pass through these channels, innervating other and/or different structures in the mental region of the head.

On the other hand, unlike congenital morphological variation, pathological changes in the teeth and the lower and upper toothrow are common in the bones of domestic animals represented in archaeological find materials. These diverse lesions are linked to multifactorial aetiologies (Baker and Brothwell 1980; Bartosiewicz 2013). The observed lesions often are minor anomalies in the form of uneven tooth wear. Mandibular osteomyelitis (a consequence of *actinomycosis*) is a highly complex condition caused by mixed infection by two different microorganisms, an *Actinomyces* and an *Actinobacillus* bacterium *(Actinomyces bovis* and *Actinobacillus lignieresi)*. It is a chronic infection, which can lead to osteolysis of the mandibula with a clear and intense periosteal proliferation zone of healthy bone tissue. In general, any changes on the teeth and mandibles can be predisposed and/or directly caused by eating rough, bulky and low quality food. In addition, a loss of teeth and periodontal disease may be due to malnutrition and lack of minerals in the diet.

Less common pathological findings were infection (manifested as osteomyelitis) and bone fractures, which is not congruent with observations previously published in the literature suggesting that these lesions occur commonly in faunal assemblages, particularly fractures (Baker and Brothwell 1980; Bartosiewicz 2008). In addition to these symptoms, some finds could only be classified as pathological changes of unknown origin. They include abnormal, clearly limited openings on the cattle acetabulum. Similar anomalies of possibly minor significance, have not been described in the veterinary literature (Thompson 2007). Osteolytic zones of such diameters can be created by bone abscesses or benign neoplastic masses (osteomas). A similar change of unknown aetiology diagnosed in this assemblage is a complete ankylosis of the scapulohumeral joint in cat. Pathologies localised in the scapulohumeral joint are *osteochondritis dissecans* and glenoidal dysplasia (Schwarze *et al*. 2015), which have been discussed in the veterinary literature. In terminal stages, this type of osteoarthropathy may lead to a deposition of osteoid mass in the intra-articular spaces, the formation of osteophytes and ossification. Although the aetiology of osteochondritis dissecans has

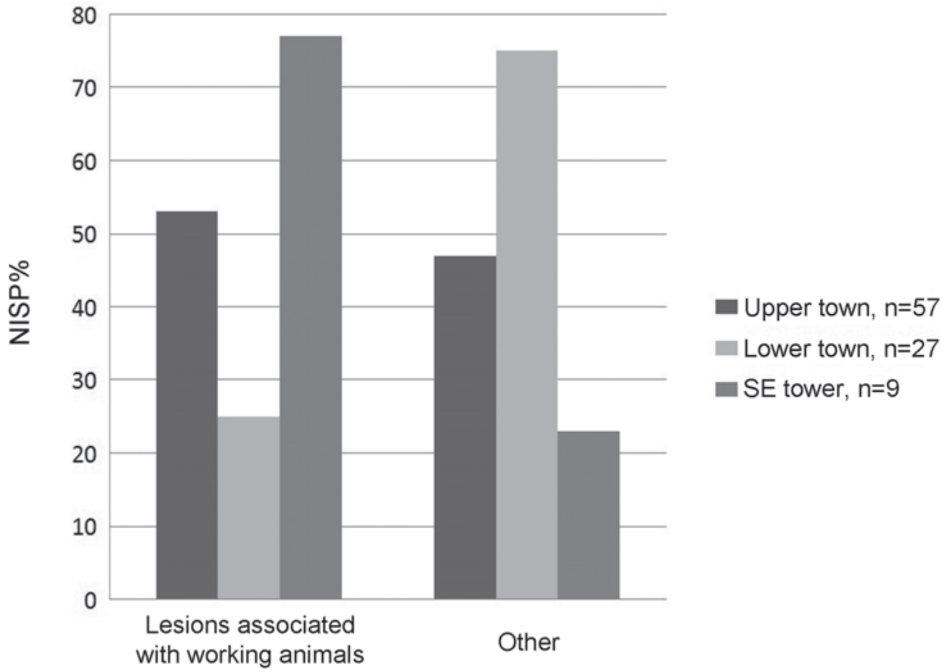

Figure 5.8. Relative frequency of pathological changes associated with working animals from Caričin Grad.

remained unclear, it is believed that diet can play an important role in the creation and development of this disorder (Ekman and Carlson 1998). Chronic osteochondrosis-dissecans usually leads to arthritic changes (Schwarze *et al*. 2015). It is questionable whether this developmental anomaly of the humeral bone head can cause complete ankylosis as seen in the case of the cat from Caričin Grad.

5.6 Conclusions

On the basis of these preliminary results it can be concluded, that the relative frequency of pathological lesions was generally low in Caričin Grad. With 0.81% of bones showing pathological changes, animals in this city appeared to have been in good health. The most frequent pathological symptoms were found on the bones of large domestic animals. They occurred predominantly in the form of degenerative bone alterations and traumatic lesions. These changes may be directly related to working in the case of cattle, horses, donkeys and camels.

Types of pathological changes and their frequencies indicate differences between sub-samples in the Caričin Grad assemblage. A higher percentage of work-related pathological changes and more remains of equids and camels came to loght in the Upper than in the Lower town. These differences could be one of indicators of the differing social status of inhabitants in Caričin Grad in the time of economic decline. Even through

the obvious decline of urban life, judging from the letter of Pope Gregory the Great of 602, the city was still the seat of the archbishop of Justiniana Prima (Ivanišević 2016, 125), probably with some parts of etablishment, state and church institutions, such as the army and municipal administration.

Dental deformations in the case of sheep/goat may have resulted from poor quality graze and/or hay nutrition at some point in time. On the other hand, a high percentage of bone inflammation, infection, and traumatic alterations in pig, particularly in the Lower town, most probably came about as a consequence of keeping animals in a limited space, which was normal practice at late antique urban settlements.

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6. Congenital Anomalies and Traumatic Injuries in Dogs from *Laodicea in Canaan* (Hellenistic Beirut, Lebanon)

Yasha Hourani

Health conditions of canids in the Levantine Hellenistic period have so far not been studied in detail. Five dog burials uncovered in Beirut, dating to the Hellenistic period, provided an opportunity to assess pathological bone changes in almost-complete and partial skeletons. This constituted a primary investigation of the health of Levantine dogs during that period. The Beirut dogs were medium-snouted and displayed harmonious proportions between body height and length, similar to those of the mediolinear canid group. They exhibited traces of acute fractures that reflect either cultural attitudes towards dogs or the working purposes for which they were kept that would have predisposed them to sudden traumatic injuries. Tendinous and ligamentous ossifications were also recorded and can be related to environmental factors or inherited disorders. Similarly, several congenital defects were noted. Symptoms of chronic diseases on the other hand were little pronounced, owing most likely to the relatively young age of the animals between 1.5 and 3 years at the time of death. On the whole, these dogs displayed less debilitating diseases than Levantine dogs in earlier periods, although they showed similar mortality patterns.

6.1 Introduction

Several sites in the Levant dating to the Hellenistic period yielded dog burials in domestic contexts. At Ashdod, articulated skeletons of nine adult and three immature canids were found in a refuse dump (Haas 1971). At Tell Gezer, in the central coastal plain of Israel, remains of 15 dogs were uncovered in Hellenistic deposits dating to the 2nd century BC, laid in an open area adjacent to two buildings. These dog burials consisted of articulated partial and complete skeletons and two isolated skulls (Gitin 1990, 19–20, 311–365[1]). At Tell Hesban, on the Jordanian highlands, dog remains were uncovered in layers dating to the late Hellenistic period (198–63 BC), including a skeleton displaying a burnt hind limb and lacking the skull (Little 1969, 237). In addition, almost-complete skeletons of three young dogs, the partial skeleton of a puppy and partially articulated bones of a neonatal and a juvenile whelp were identified (von den Driesch and Boessneck 1995, 73–74, tab. 5.12). At Tell Abou Danné in northern Syria, scattered remains, as well as partial and almost-complete skeletons of a minimum number of 14 dogs were uncovered in two pits dating to the second half of the 2nd century BC

along with scattered bones of other mammals, birds and fish (Doyen and Gautier 1985). Amongst the dogs were six adults (out of which two were male), three subadults, a puppy and an individual of perinatal age.

The archaeological context of the finds at these Hellenistic sites is well-defined. However, although in some cases the biological features of the dogs such as age, sex and morphological aspects were reconstructed, the health conditions of the animals have so far not been a subject of detailed investigation. Hence, there remains a gap in the overall comprehension of the life history of dogs buried in the Levantine Hellenistic period.

A rescue excavation held in Beirut's central district in 2013 yielded five dog burials dating to the Hellenistic period, more specifically to the 2nd century BC. This discovery provided an opportunity to investigate the biological characteristics of dogs from Hellenistic Beirut. An assessment of the morphological characteristics was undertaken and an emphasis was placed on the reconstruction of their health status through the examination of the presence or absence of altered skeletal elements.

6.2 Beirut in the Hellenistic period: Historical and archaeological context

In 333 BC the Phoenician cities fell under the control of the Macedonians after the victory of Alexander the Great over the army of Darius III (Sartre 2001, 68–77). Incorporated intermittently into the Seleucid and the Ptolemaic Kingdoms after Alexander's death, Phoenicia was definitively controlled by the Seleucids in the last quarter of the 3rd century BC until 64 BC when Pompey the Great annexed Syria and Phoenicia as a new Roman province (Sartre 2001, 441–447). During the Hellenistic period however, the Phoenician cities were granted their liberty and held their mercantile tradition and Mediterranean trade connections.

Developed on a promontory facing a sheltered natural bay, Beirut constituted an active port-city within the Mediterranean trade networks (Guillon 2013, 283) and benefited from flourishing economic activity (Boksmati 2009). During the reign of Antiochus IV, Beirut received the name of Laodicea and the city struck currency during the 2nd century BC in the name of "Laodicea who is in Canaan" (Hill 1910 cited in Jidejian 2002). The 2nd century was also the period when trade with the Aegean region flourished (Aubert 2002). A new production of local ceramics emerged and the city experienced considerable urban expansion (Aubert 2002). Around 143 BC, Beirut was destroyed by Tryphon in his fight against Antiochus VII, but the city recovered quickly (Jidejian 2002, 57–58).

Rescue excavations held in Beirut's central district since the 1990s revealed the fortifications of the Hellenistic city (Karam 1997) and allowed the identification of the residential, commercial, industrial, artisanal, religious and funerary areas relating to this period (Curvers and Stuart 1997, 189–198; Boksmati 2009). An area located at the north-western fringe of the ancient city, lot 1338 of the modern Mina-el-Hosn quarter, site code BEY198 (Figure 6.1), was excavated in 2013. The site served as a human burial-ground in the Late Iron Age as evidenced by the shaft tombs uncovered (W. Khalil and M. Abi Zeid, in preparation). In the Hellenistic period, and in particular during

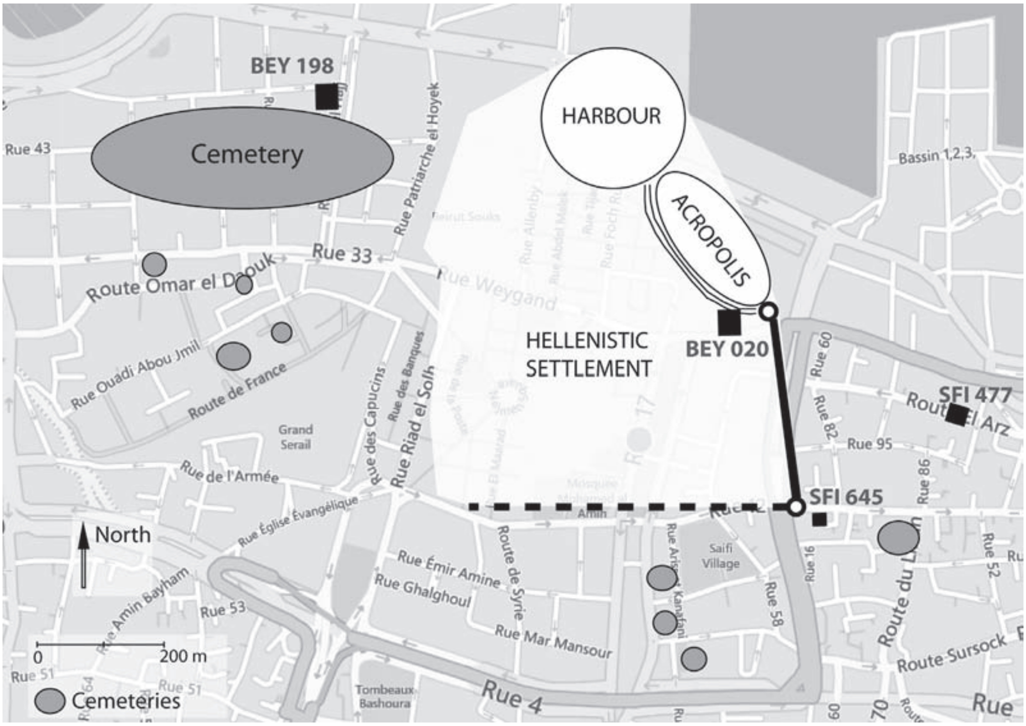

Figure 6.1. Location of site BEY 198 in the Mina-el-Hosn quarter of the modern central district of Beirut and north-west of the Hellenistic settlement. Three sites (BEY 020, SFI 645, SFI 477) that yielded dog burials dating to the Persian period are also depicted on the map, located to the east of the ancient settlement (modified after H. Curvers 2013 with his kind permission).

the 2nd century BC, part of the site was used as a quarry, while the remaining part served as a dumping area (W. Khalil and M. Abi Zeid, in preparation). The presence of a quarry at that time concurs with the expansion of the city during the 2nd century BC.

Also in this specific century, five dogs were buried at the site. They were deposited in abandoned structures and in refuse layers. Scattered dog remains and groups of bones in partial anatomical connection were similarly retrieved from refuse dumps. The latter remains could have constituted corpses left uncovered following deposition resulting in the disappearance of several anatomical relationships and the loss of skeletal elements, buried corpses disturbed by a later action, or secondary deposits made prior to the full disintegration of the articulations.

6.3 Material

With the aim of assessing the health conditions of the buried dogs, this study focuses on the five individual primary deposits that consisted of articulated partial and almost-complete skeletons. These cases offered the opportunity to assess pathological lesions on the skeletons in conjunction with other biological features such as age and dog

morphotype. One of the dogs (canid 2462) had been buried during the abandonment phase of the human tombs, before quarrying activity began at the site. The other four individuals (canids 2445, 1314, 924 and 904) were buried after the site was transformed into a quarry. The dogs were laid in various contexts within different sectors of the site, such as a refuse dump, an abandoned tomb, a cavern and a pit, indicating that there was no intention to lay out a particular burial-ground for dogs, but that they were buried where space was available at the fringe of the settlement.

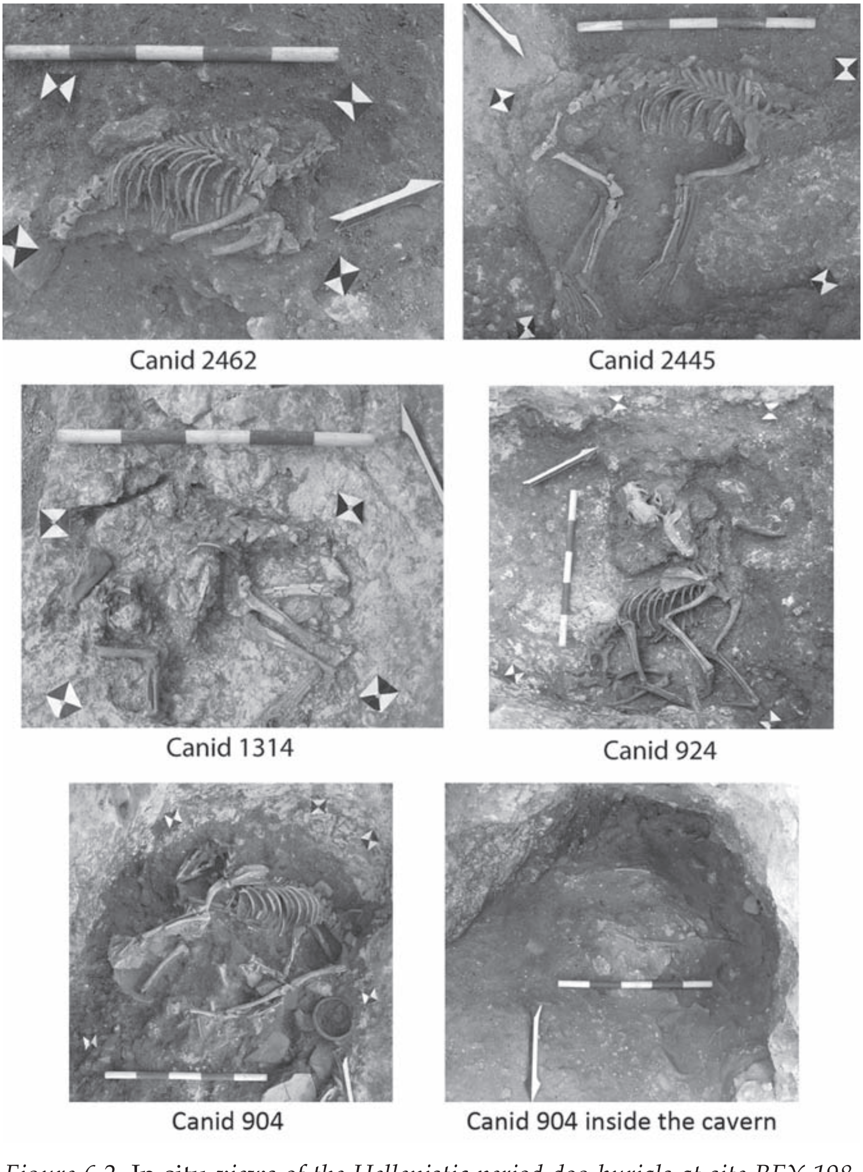

Figure 6.2. In situ *views of the Hellenistic period dog burials at site BEY 198.*

Specimen 2462 was laid in one of the shaft tombs after it was no longer used, as suggested by the collapse of the ceiling and the infiltration layers that preceded the placement of the dog. This specimen consists of a partial skeleton, truncated at the side falling to the east by a later trench. The dog was laid on its left side head north (Figure 6.2).

Specimen 2445 was laid in the refuse dump area. It was covered by chiselling debris, likely generated by the exploitation of the quarry that was ongoing at the time the burial was made. This specimen consists of an almost-complete skeleton with a highly fragmented skull. The individual was laid on its left side, head to the north-west. The body was extended but the limbs were slightly flexed (Figure 6.2).

Specimen 1314 was buried in a circular pit dug into the bedrock at a time when the exploitation of the quarry was already set. It consists of a partial skeleton, horizontally truncated by modern activity. The individual was laid on its right side, in a curled position conforming to the shape of the pit, head oriented west (Figure 6.2).

Specimens 924 and 904 were laid successively at the inner end of a small natural cavern in the substratum. Specimen 924 was carefully placed on its left side, head to the north, and limbs flexed in front of its thorax (Figure 6.2). The individual was covered by a thin layer of sediment. Above this layer, a few pottery sherds were placed, upon which specimen 904 was laid. The cranium, the right hemi-mandible, the first cervical vertebra and the right femur of canid 924 were displaced. The dissociation of the skeletal elements occurred before or during the placement of specimen 904. This indicates that specimen 924 was already in an advanced stage of decay when specimen 904 was deposited. The position of 904 shows that less care was taken when the corpse was deposited. The individual was laid on its right side, head to the south-south-east. The left fore- and hindlimbs were extended while the right limbs were flexed. The left forelimb lay at a higher level than the rest of the body, indicating that the position of the corpse followed the slope of the underlying fills. The head lay on the base of the cut in ventral view. The atlas and the axis were rotated in the same direction as the skull and also appeared in a ventral view. Hence, the inverted position of the head is more likely to be in an original position than a secondary, resulting from taphonomic movement (Figure 6.2).

6.4 Methods

6.4.1 Age, sex, size and cranial typology

Age-at-death of the dogs was estimated based on the degrees of fusion in the cranial (Barone 1976, 53) and postcranial skeleton (Barone 1976, 53; Evans and Christensen 1979; Watson *et al*. 1986), dental eruption (Silver 1969) and extent of wear of the lower first molar tooth (Horard-Herbin 2000).

The individual's sex was determined on the basis of the presence or absence of the *baculum* (Evans and Christensen 1979). In the case of partial or poorly preserved skeletons, sex could not be determined.

The height at the withers was estimated based on the multiplication coefficients developed by Harcourt (1974).

The crania presented here were too fragmentary and yielded no measurements for the calculation of discriminant cranial indices (Stockard 1941; Ellenberger and Baum 1943; Brehm *et al*. 1985; Lignereux *et al*. 1991) commonly used to assign archaeological

specimens to a skull type. Morphological assessments based on the visual consideration of the allometric variation of the face (Lignereux *et al*. 1991) were therefore used to evaluate the cranial type. The craniological terms thus used concern three groups of dogs: dolichocephalic dogs are characterised by a narrow, thin and long-snouted cranium; mesocephalic dogs are medium-snouted, showing a larger snout than the dolichocephalic type; brachycephalic dogs have a broad and short-snouted cranium.

6.4.2 Pathologies

The skeletons were examined macroscopically (Bartosiewicz 2013, 40) for bone surface modifications. Pathological changes were first assessed in each skeleton individually. Diagnoses of identified pathologies were then grouped into categories and their frequency within the sample assessed.

Intra vitam tooth loss (Baker and Brothwell 1980, 155) was referred to as dental anomaly. In addition to tooth loss, this category includes other lesions such as tooth breakage and unusual wear (Baker and Brothwell 1980, 147; these, however, occurred only in the Persian period collection, represented in parallel with the BEY 198 collection in Figure 6.11 below).

Bone fractures were referred to as traumatic injuries as they appeared to be related to trauma rather than to pathological processes (Ortner 2003, 125; Groot 2008). Structural deformities were referred to as congenital anomalies following Baker and Brothwell (1980).

Single pathological changes affecting the articular surfaces, such as the development of marginal osteophytes, were referred to as joint disease (Baker and Brothwell 1980, 115), although usually at least three out of four alterations should be present in order to diagnose joint diseases (Baker and Brothwell 1980, 115), be they proliferative articular diseases (osteoarthritis, intervertebral disc disease) or erosive arthropathies.

Finally, enthesopathies (Hawkey and Merbs 1995; Jurmain 1999; Bendrey 2008) and ligamentous ossifications (Bendrey 2007; Bartosiewicz 2013, 137–139) were grouped into the same category.

Pathologies in the BEY 198 material were then compared to an earlier period collection of canid specimens from Beirut. This latter assemblage, dating to the Persian period, comprised 12 individuals displaying evidence of skeletal pathologies (Hourani 2018).

The various categories of pathological lesions were represented in a diagram illustrating their frequency in the BEY 198 material in comparison to the Persian sample. Two additional categories were also included in the diagram: linear enamel hypoplasia, related to physiological stress (Dobney and Ervynck 2000), and infectious diseases (Bartosiewicz 2013, 91–104), diagnosed in the dog remains of the Persian collection. The frequency of pathological symptoms was counted by the number of individuals and distributed by age group (1.5–2 years and over 2 years of age) for each period.

Comparisons between the two periods were also attempted through the calculation of a frequency index for each pathology and each period, by dividing the number of occurrences by the total number of individuals (n=5 for the Hellenistic period and n=12 for the Persian period). Regarding the dental anomalies, the number of occurrences was

divided by the number of specimens in which the maxilla or the mandible were preserved (*i.e*. n=4 for the Hellenistic and n=11 for the Persian collection). The assemblage sizes are undoubtedly very small to suggest conclusive evidence regarding differences in pathological prevalence and interpretation of the frequency index is partly hampered by the unequal size of the two samples. Nevertheless, this comparison provides a preliminary notion of canid health during the two periods, until additional archaeological finds of dogs help shed more light on this matter.

6.5 Results

The Hellenistic period dogs from site BEY 198 displayed a certain variation in body size. Nonetheless, the conformation of the limbs (*i.e*. the ratio between the total length and the slenderness index of the long bones) suggested that the specimens resembled rather mediolinear dogs (Hourani unpublished). These are characterised by harmonious proportions between body height and length, such as the lupoid dogs (Regnault 1903; Galy 2004, 8; Belhaoues 2011, 97). Similarly to the earlier canids recovered from the Persian levels of Beirut (Hourani 2018), the Hellenistic specimens did not show great robustness as Molosser dogs characterised by a massive body and a short-snouted head (Megnin 1897; Galy 2004, 9; Belhaoues 2011, 96), nor extreme slenderness as sighthounds (Hourani unpublished). Morphological assessments of the crania of specimens 904 and 924 suggested that both belonged to rather medium-snouted dogs. Although, as previously mentioned, the state of preservation of the crania did not allow the calculation of cranial indices, specimens 904 and 924 might be sub-mesocephalic or sub-dolichocephalic, showing an intermediate snout length between mesocephalic and dolichocephalic dogs. They were thus similar to the Persian period dogs (Hourani 2018). According to the classification by Belhaoues (2011, fig. 48), examples of sub-dolichocephalic and sub-mesocephalic dogs can be best illustrated respectively by the modern breeds of the German shepherd and the Brittany spaniel.

None of the Hellenistic specimens presented a case of oligodontia, polyodontia or excessive teeth crowding. In the four preserved skull specimens, a slight crowding of the lower fourth premolar and first molar was noticed as well as a slight encroachment of the lower third molar on the vertical ramus of the mandible (Figure 6.3). The position of the lower premolars varied slightly; for instance, in specimen 2445, the lower premolars were more spaced than in specimen 2462. Lastly, the dogs were between 1.5 and 3 years at the time of death and four out of the five individuals showed pathological changes.

Canid 2462, of indeterminate sex, was 1.5–2 years old at the time of death. This individual displayed a healed fracture as shown by the evidence of remodelled bone with callus formation (Lovell 1997, 145; Ortner 2003, 126–128) on the spinous process of the 4th thoracic vertebra (Figure 6.4). This indicates an acute transverse fracture (Groot 2008), resulting from direct trauma (Ortner 2003, 120–125; Groot 2008). Transverse fractures are more common in non-accidental than accidental injuries, hence indicating trauma more likely resulting from physical abuse rather than accidental falls (Tong 2014). Periostitic and osteomyelitic activity were absent from the site of fracture, indicating that complications associated with post-traumatic infections did not occur (Lovell 1997, 46; Groot 2008). Additionally, this individual exhibited bone abnormalities

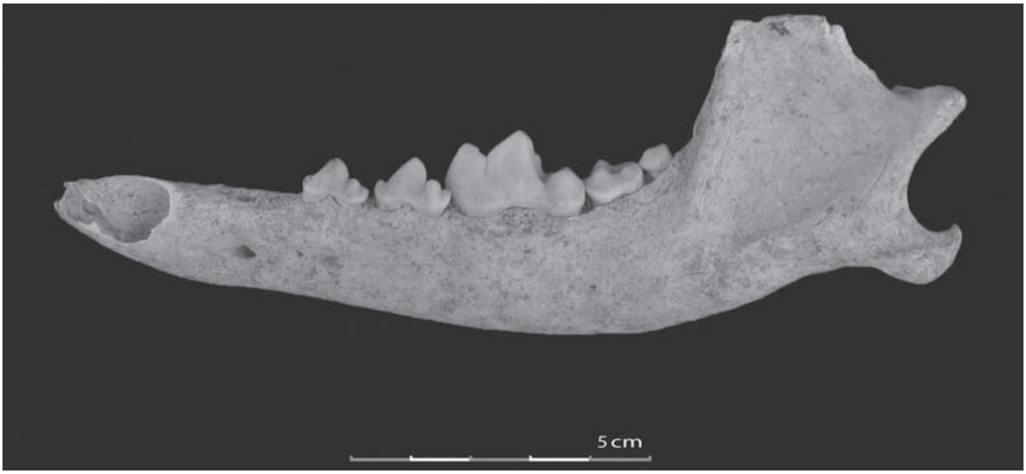

Figure 6.3. Lateral aspect of the left mandible of canid 924 showing a slight crowding of the fourth premolar and first molar, a slight encroachment of the third molar on the vertical ramus of the mandible and intra vitam loss of the first premolar with remodeling of the empty alveolus.

Figure 6.4. Lateral aspect of the 4th thoracic vertebra of specimen 2462 showing a callus formation on the spinous process.

Figure 6.5. Cranial aspect of the 5th thoracic vertebra of specimen 2462 lacking the left cranial articular process.

of congenital origin. The 3rd to the 8th thoracic vertebrae lacked cranial and/or caudal articular processes (Figure 6.5).

Canid 2445, also of indeterminate sex, was 2–3 years old at the time of death. The estimated withers height of this specimen is *c.* 53 cm. Canid 2445 exhibited a healed acute fracture with callus formation on the 8th right rib (Figure 6.6). Furthermore,

Figure 6.6. The 8th right rib of specimen 2445 showing a callus formation on the corpus.

Figure 6.7. Lateral aspect of the 6th thoracic vertebra of specimen 2445 showing exostoses at the apex of the spinous process related to the ossification of the supraspinous or interspinous ligaments.

this individual showed bone changes in a number of vertebrae. Exostoses at the apex of the spinous process of the 6th thoracic vertebra (Figure 6.7) suggested ossification of the interspinous or supraspinous ligaments (Bartosiewicz 2013, 139) that might have been accompanied by chronic inflammation, whereas the slight distortion of the spinous process of the 7th and 10th thoracic, and of the 5th and 7th lumbar vertebrae likely resulted from congenital anomalies (L. Bartosiewicz, pers. comm.).

Canid 1314 was 1.5–2 years old at the time of death. The state of preservation of this skeleton allowed neither size estimation, nor the detection of bone pathologies. Canid 924 is a male individual, aged 2–3 years at the time of death. The estimated withers height of this specimen is *c*. 63 cm. Canid 924 underwent *intra vitam* loss of the left first lower premolar with remodelling of the empty alveolus (*cf*. Figure 6.3). Tooth loss is usually caused by periodontal disease resulting in chronic inflammation along the gum line (Lane 1981). This condition is plaque-related, mainly triggered by diet quality that influences the composition of the plaque (Coyler 1936, 677, cited in Bartosiewicz 2013, 182). The alveolus was completely absorbed indicating that the individual lived long after the loss of the tooth (Bartosiewicz 2013, 178). Furthermore, ossification of the interosseous tibio-fibular ligaments resulted in the fusion of the distal diaphysis of the tibia and fibula. Additionally, some variations in the skeleton of this individual may reflect congenital anomalies. A slight distortion of the spinous process occurred in the 7th and 13th thoracic vertebrae. Also, cortical pitting was noted on the cranial aspect of the proximal diaphysis of the metacarpals and metatarsals. The pitting occurred at the attachment site of the muscle *extensor carpi radialis* in the 2nd and 3rd metacarpal bone (Barone 1976, 228, pl. 307), possibly suggestive of microtraumatic lesions (Hawkey and Merbs 1995). However, this condition appeared on all the metapodials, including the

Figure 6.8. Cranial aspect of the 4th right metacarpal of specimen 924 showing cortical pitting on the proximal diaphysis.

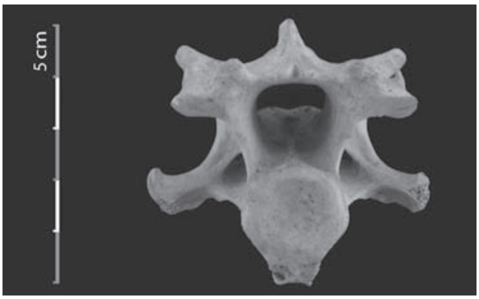

Figure 6.9. Caudal aspect of the 5th cervical vertebra of specimen 904 displaying marginal osteophytes on the ventral side of the vertebral endplate.

4th metacarpal (Figure 6.8) on which there are generally no muscle insertions on the cranial aspect (Barone 1976, 228, pl. 307). Additionally, the perforations do not occur in parallel with any form of additional lesions such as bone proliferation, erosions, deformities or necrosis. They therefore do not appear to constitute a symptom of an inflammatory reaction or infectious disease, but rather may be linked to a congenital anomaly.

Canid 904, of indeterminate sex, was aged around two years at the time of death. The estimated withers height of this specimen is *c.* 61 cm. Canid 904 had suffered a traumatic injury as the corpus of the 6th left rib displayed a callus indicative of a healed fracture. In addition, the 5th cervical vertebra exhibited marginal osteophytes at the ventral side of the caudal endplate (Figure 6.9). This modification is visible on a single vertebra and is not associated with eburnation or pitting on the vertebral body. It therefore cannot be said to be a symptom of advanced osteoarthritis or intervertebral disc disease. On the other hand, the right humerus showed changes in the form of a roughened zone below the *caput humeri* at the attachment site of the brachial muscle (Barone 1976, pl. 252) that might have been the commencement of enthesopathic manifestation (Figure 6.10). These rugged markings develop when tendinous or ligamentous insertions are subjected to repetitive stress (Hawkey and Merbs 1995, 324), but can also be age-related and even genotypically influenced changes (Jurmain 1999, 144–149; Bendrey 2008).

In summary, traumatic injuries were observed in three specimens (canids 904, 2445 and 2462), dental anomalies in one specimen (canid 924), ligament and tendon ossification in three specimens (canids 904, 924 and 2445), periarticular osteophytes in one specimen (canid 904) and lastly, congenital anomalies in three specimens (canids 924, 2445 and 2462; Figure 6.11).

6.6 Discussion

Figure 6.10. Caudal aspect of the right humerus of specimen 904 displaying rugged markings, indicated by the white arrow, on the proximal diaphysis below the caput humeri.

Dogs uncovered at lot BEY 198, 53–63 cm high at the withers, are close to the general size range of Hellenistic dogs in the Levant, though slightly taller. At Tell Hesban, a Hellenistic specimen is c. 50 cm high at the withers (Weiler 1981, tab. 36) and at Tell Abou Danné (estimated by the authors following von den Driesch and Boessneck 1974) dogs are medium-snouted with a height of 51–59 cm at the withers (Doyen and Gautier 1985). Dogs at BEY 198 are also slightly taller than the Persian period dogs of Beirut which stand 46–57 cm at the withers (Hourani 2018) and of Ashkelon that stand at 48–61 cm (Wapnish and Hesse 1993). Hellenistic and Persian dogs in the Levant stand therefore between 45–63 cm at the withers, according to the archaeozoological data at hand. Small (less than 40 cm) and very large dogs (more than 70 cm) are so far absent in the archaeological record.

Dogs at BEY 198 showed several pathological bone changes. However, there were no symptoms that could be linked directly to their death. Traumatic injuries observed in three specimens are unlikely to have been caused by intraspecific aggression as neither puncture fractures were observed (Groot 2008) nor were injuries directed at the head and shoulder region as is generally the case in bite wounds (Baranyiová *et al*. 2003, 58–59). Conversely, they are more likely to have been sustained in interspecific conflict such as being kicked or gored by large animals in case the dogs used for herding (Teegen 2005; Groot 2008). The presence of fractures in several individuals is also very suggestive of trauma inflicted by humans. Spatial proximity and intensified interactions between humans and dogs can result in mistreatment (Bökönyi 1984, 111; Groot 2008), be it deliberate in nature or simply inadvertent (Bartosiewicz 2013, 90). Moreover, ribs and vertebrae are the most likely elements to bear traces of animal abuse (Teegen 2005, Thomas 2005). In any case, callus formation observed at the fracture sites in two ribs and a vertebra indicate that the individuals lived for at least several weeks after the incident. The sequence of bone repair is in fact relatively long. The fractured bone reunites after about two weeks by a fibrocartilaginous callus (Aufderheide and Rodriguez-Martín 1998, 21) that is subsequently converted into a

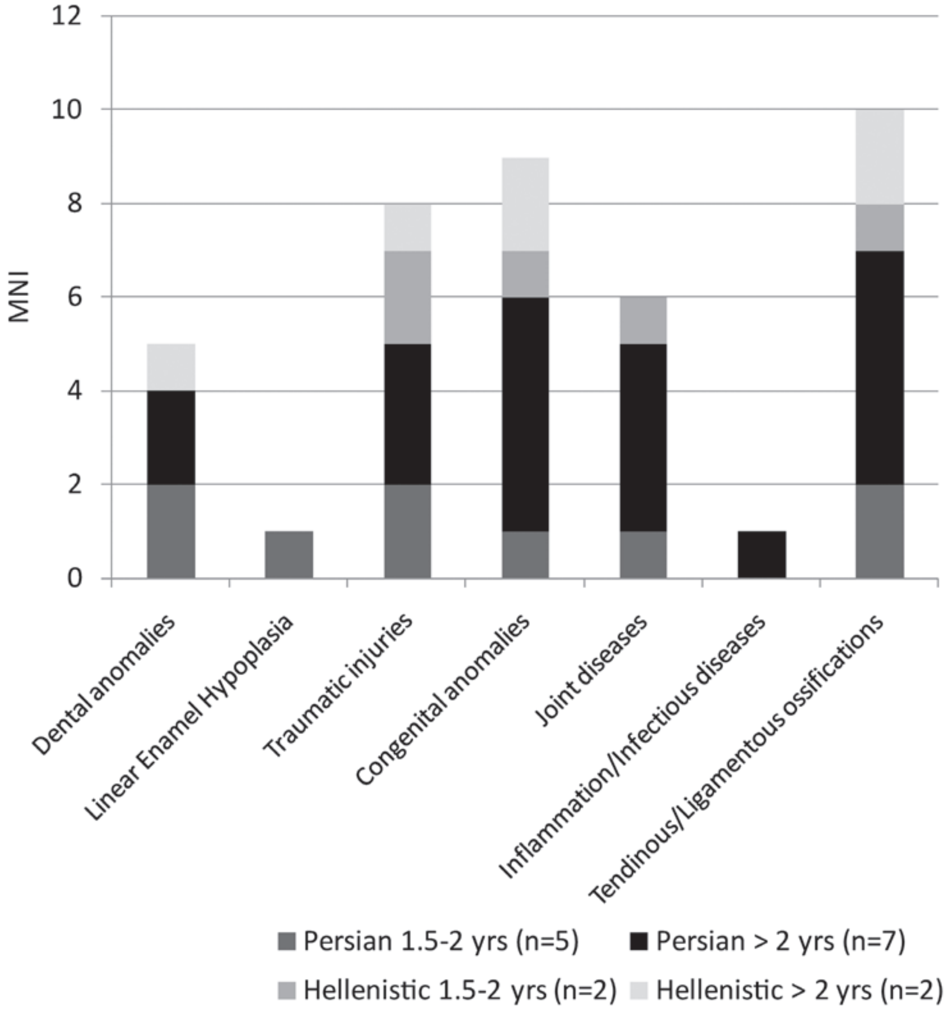

Figure 6.11. Occurrence of pathological lesions in the dogs of the Hellenistic site BEY 198 in comparison with a Persian period collection from Beirut (Hourani 2018). Pathological lesions are distributed by period and by age group (1.5–2 years and over 2 years).

bony callus (Ortner 2003, 126–128; Groot 2008) about three or four weeks after the injury had taken place (Fossum *et al*. 2002, 837–838; Märtson 2006, 42). Although periodontal disease can reduce the feeding ability of the animal (Baker and Brothwell 1980, 154; Hoefs and Bunch 2001) leading to its death, the loss of one small premolar should not have seriously affected canid 924. Furthermore, symptoms of joint disease, such as vertebral periarticular osteophytes, did not appear in an advanced stage nor did they affect several loci of the spine. In general, conditions such as periodontal disease,

vertebral osteophyte formation, tendinous and ligamentous ossifications advance with age (Baker and Brothwell 1980, 154; Bartosiewicz 2013, 201; Bendrey 2007). The individuals buried at lot BEY 198, being not older than three years at the time of death, have not been severely affected by diseases for which old age is a predisposing factor. Nevertheless, such conditions may have different aetiologies; and since they were expressed to a certain degree already at an early age in the dogs' life, the impact of environmental factors (Bendrey 2007), malnutrition (Baker and Brothwell 1980, 153) and inherited disorders (Bendrey 2007; Bartosiewicz 2013, 201) behind similar symptoms must be presumed. Also, congenital anomalies can in some instances be triggered by environmental factors, nutritional state (Baker and Brothwell 1980, 34) and inbreeding (Wynbrandt and Ludman 2008, 101). They are nonetheless unlikely to have directly affected the health of the dogs (Miklíková 2008). Therefore, no debilitating chronic diseases or lethal conditions were observed in these dogs. It should, however, be borne in mind that skeletal responses to illness can be limited (Grimm 2008), which hinders attempts of diagnosis.

With regards to other Hellenistic collections, Doyen and Gautier (1985) in their description of one of the skeletons at Tell Abou Danné mentioned that it did not display pathological lesions. They gave no information about the remaining skeletons. At Tell Hesban, two traumatic injuries and spondylosis deformans were mentioned without dating (Weiler 1981, 172–173). Lastly, the other aforementioned reports on Hellenistic period dog burials did not point out any skeletal alterations either.

Compared to Persian period dogs from Beirut, that present parallel mortality patterns, the dogs of site BEY 198 showed similar pathological changes, although in different frequencies and to varying degrees (Figure 6.11). The prevalence of traumatic injuries and congenital anomalies was higher in the Hellenistic collection (Table 6.1). Nonetheless, traumatic injuries occurred in one skeletal element, a rib or a vertebra, in each of the Hellenistic cases, while three Persian specimens showed several fractures in ribs, vertebrae or the cranium (Hourani 2018, tab. 5). Likewise, lesions related to chronic conditions of the joints appeared to have been far less severe in the affected Hellenistic dog than in the Persian dogs. Intervertebral joints were not excessively altered, and facets of costo-vertebral and limb joints were not modified at all. Ossification of the supraspinous and interspinous ligaments was also far less pronounced in the affected Hellenistic specimen than a Persian case in which this condition led to the fusion of two thoracic vertebrae (Hourani 2018, fig. 25). Moreover, periodontal disease was less advanced in the Hellenistic specimen in comparison to the two Persian cases in which *intra vitam* loss of several teeth was recorded. One of those Persian dogs also exhibited irregular wear and tooth breakage. A third Persian specimen also exhibited infection of the mandibular periosteal bone (Hourani 2018, figs 14 and 15). Linear enamel hypoplasia and lesions related to infectious diseases were not observed in the Hellenistic specimens. Such pathologies were, on the other hand recorded, in the Persian collection (Hourani 2018, figs 13 and 16).

Canine pathologies are common at other Iron Age near-eastern sites. The Ashkelon Persian period dog burials revealed that *c*. 5% of the subadult (6–18 months) and adult individuals (n=1238) carried pathological symptoms associated with parasitic infections, dental anomalies and traumatic injuries (Wapnish and Hesse 1993; 2008). Beyond the Levantine region, at Isin in southern Mesopotamia, earlier period dog remains (n=33)

Table 6.1. Frequency index of the pathological lesions observed in the dogs of the Hellenistic site BEY 198 (n=5) and of a Persian period collection from Beirut (n=12; Hourani 2018).

Pathological conditions	*Hellenistic sample (n=5)*	*Persian sample (n=12)*
Dental anomalies	0.3	0.4
Linear Enamel Hypoplasia		0.1
Traumatic injuries	0.6	0.4
Congenital anomalies	0.6	0.5
Joint diseases	0.2	0.4
Inflammation/infectious diseases		0.1
Tendinous/ligamentous ossifications	0.6	0.6

recovered from layers dating to 1000 BC showed a high rate of pathological lesions where 50% of the young adults and 70% of the adults showed *intra vitam* tooth loss or fractures of the limbs and feet (Boessneck 1977).

The available archaeozoological data tend therefore to suggest that Hellenistic dogs in the Levant present fewer pathological lesions than dogs in earlier periods of the Near East. However, faunal reports published previously may have left out observations of skeletal alterations or these were not deemed worthy of mention. Moreover, the limited number of burials in Beirut prevents making definitive statements about the health conditions of Hellenistic period dogs.

From a different perspective, the occurrence of severe pathological lesions may reflect aspects of human culture that governed the relationship between humans and dogs (Miklíková 2008). For instance, advanced chronic conditions address the question of whether disabled animals survived in spite of a careless human attitude or, conversely, thanks to the care provided to pets (Bartosiewicz 2013, 178). The latter assertions are stated in conjunction with the appearance of very small-sized dogs in the Roman Empire considered as pets (MacKinnon and Belanger 2006); and with the trend of keeping luxury dogs, in the European high Middle Ages. Advanced stages of *intra vitam* tooth loss in these dogs – sometimes even in young individuals – can be associated with a rich, in some instances cereal-based, diet (Bartosiewicz 2013, 178, 180). On the other hand, very advanced degenerative osteoarthritis which would impair the animal's movement was seldom observed in pre-Roman dogs, indicating that the latter did not live to an advanced age as observed in Roman period lap dogs (Clark 2000). In the case of BEY 198, it is therefore problematic to assert whether dogs did not suffer from advanced chronic diseases because of some degree of human care or simply owing to the relatively young age-at-death of the individuals available for study. The first assumption would underline an ambivalent attitude towards dogs (Thomas 2005), kept for utilitarian purposes and taken care of but, as suggested by the traumatic injuries, kicked and beaten when humans got exasperated. The second view concurs more with the age-span that prevails in pre-Roman dogs, and with the fact that, in the Levant, diversification of dogs – in particular the emergence of small dogs considered as pets who survived longer and were therefore predisposed to chronic diseases – does not

seem to occur prior to the Roman period, in Persian or Hellenistic times (Doyen and Gautier 1985; Wapnish and Hesse 1993; Çakirlar *et al*. 2014; Hourani 2018). Lastly, the study of a larger collection of canid remains would provide a more accurate basis for delineating the mortality profile of the Hellenistic dog population and would shed more light on its health status since specific mortality patterns, such as high or low proportions of immature animals, reflect the welfare of a population (Thomas 2005) when deliberate culling is not proven.

6.7 Conclusions

Dog burials at site BEY 198 provided an opportunity to investigate the biological characteristics of partial and almost-complete canid skeletons dating to the Hellenistic period. The five individuals were between 1.5 and 3 years of age at the time of death. The state of preservation of three specimens allowed morphological assessment. These were mediolinear dogs, *c*. 53–63 cm high at the withers. The tallest individual was a male dog. Four specimens displayed pathological changes. These exhibited traces of traumatic injuries that reflect either cultural attitudes towards dogs or the purpose for which they were kept, such as guarding or herding that would have predisposed them to sustaining sudden traumatic injuries. Symptoms of periodontal and joint diseases were not severe in these dogs, while symptoms indicative of infectious disease were not attested. The absence of debilitating chronic diseases could be linked to the young age of the animals. Tendinous and ligamentous ossifications on the other hand, may be related to environmental factors or inherited disorders. Several congenital anomalies were also recorded. Such pathological changes are said to occur among more or less isolated populations. With regards to the Hellenistic period, this assertion cannot be linked to human influences on genetic isolates such as selective breeding, but to a secluded dog population living in or around the walled city.

The assessment of pathological changes provided a primary investigation of the health status of dogs during the Levantine Hellenistic period. It should be followed by the study of larger collections to establish a more reliable evaluation of the overall welfare of dogs at Levantine sites after the spread of Greek culture in the eastern Mediterranean and before the advent of the Roman era.

Note

1 A forthcoming publication on canid biometric data from Tell Gezer and other sites from Israel and the Palestinian Authority would provide further information on Hellenistic period dog burials of Tell Gezer. A data table is now available online (Horwitz *et al.* 2016), while publication was expected in June 2017.

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7. Reviewing the Pathology and Welfare of Dogs in Roman Britain

Lauren Bellis

The study of animal palaeopathology has been on the rise in recent years, and works on identifying pathological change in faunal materials have been produced in increasing numbers. With this, species-specific work and identification is an important aspect. Major domestic animals, such as cattle and horses, have an increasing body of work dedicated to specific issues and their relation to human activity; for instance, the link between pathological lesions in cattle feet and their use for traction.

Dogs, however, occupy an interesting position. They have a high number of burials relative to other domesticates and are usually the most represented species after cattle, sheep, pigs and horses in many time periods and locations. They are also the species in closest contact with humans on a daily basis. Yet comprehensive work on the conditions that most frequently afflict them is thin on the ground; the studies that examine dogs tend to use small amounts of data, a single case or sometimes focus on fractures alone.

This paper will contribute to filling the gap in dog-specific studies using the results of a large review of faunal data in Roman Britain. All forms of pathological conditions indicated will be discussed, along with their variation across the Roman period and between urban and rural sites. Aetiology will be considered, particularly in relation to the welfare of dogs and their relationships with human owners.

7.1 Introduction

Dogs had immense cultural importance within Roman society, reflected by their prominence both in Roman material culture and a diverse range of ancient literature. They were referenced in works ranging from agricultural texts to comedy, and represented in artefacts as diverse as statues and mosaics to game pieces and jewellery. This attitude influenced Rome's provinces, which increased in dog-related material culture and more varieties of canine from their annexation (Bartosiewicz 2000; Colominas 2016). Nowhere is this more apparent than in Roman Britain, where dogs in the preceding Iron Age were not particularly diverse in morphology, typically only 29–58 cm in withers height (Harcourt 1974). From the final years of the Iron Age, very small dogs began to appear in the archaeological record (Clark 1995; 2000). Some of these dogs had a new skull conformation: they were short and flat like a bulldog or pug, a cranial form known as *brachycephaly*. Upon the arrival of Romans new varieties rapidly increased in size and expanded across the entire province. The variability in withers height increased to the 21–71 cm range; Baxter 2010, 2; Harcourt 1974).

Although clear morphological changes in dogs occurred with Britain's annexation, it is still unknown precisely how the influx of Roman peoples changed the way humans interacted with and treated dogs within Britain. This will be investigated through the study of pathological changes in the physical remains of dogs, and in doing so move beyond an "interesting specimens" approach (Thomas and Mainland 2005, 1), but rather examine wider patterns and trends in their manifestation.

7.2 Materials and methods

Secondary reports formed the basis for study. These were obtained through a systematic search of published, unpublished and "grey" literature (reports that have been written and circulated, but not officially published). From these reports, associated bone groups (ABGs) that had documented pathological changes (or lack thereof) were selected and recorded for the current study. ABG is a term used to refer to three types of remains (Morris 2011, 12–13):

1) in articulation,
2) deposited in articulation, disarticulated through taphonomic processes, but can still be shown to be from a single animal,
3) deposited as disarticulated, but in association with one another and from a single animal.

However, as two articulated vertebrae or a couple of bones from a single limb may be sufficient to be classed as an ABG, a further criterion was added: that remains come from more than one body part of the dog. This allows for the examination of dog skeletons that are incomplete, but not so small that they form only a single limb or other body region.

A total of 68 associated bone groups (ABGs) that had shown pathological lesions (or lack thereof) were selected, originating from 33 sites in total (Table 7.1). Nearly a quarter of these were either documented to be complete or near-complete, 47% were described to be partial skeletons while 29% were of unknown completeness. Although the geographical location of these sites spans the whole of England and Wales, most of the dog remains originate from the Midlands, East Anglia and the South-East regions of England, primarily because far fewer excavations have been undertaken outside of these regions (Taylor 2007, 15–17).

7.3 Results

Most of the 68 ABGs have no information on the sex of the individual; only 9% were specified as male and 4% as female. While this is not unexpected, given the difficulty of determining the sex of dogs without the presence of the baculum (penis bone), the lack of this information precludes the analysis of pathological conditions within the context of the animals' sex.

Most of the dogs are adults, with only 17 (25%) representing juveniles while one (1.5%) is of indeterminate age. Pathological conditions were not investigated specifically in juveniles, due to the greater difficulty in identification (as fractures may heal without permanent

Table 7.1. List of sites with numbers of ABGs present at each type of settlement (including adults and juveniles; A=adult, J=juvenile).

Site Name	*Phase*	*No. ABGs*	*Source*
Military sites			
Derby Northwest	Early Roman	1 A	Harman 1986
Segontium	Late Roman	1 A	Noddle 1993
Military total		*2*	
Rural sites			
Bainesse Farm	Roman	1	Meddens 1990
Barton Court Farm	Late Roman	1 J	Wilson and Harcourt 1984
Bluntisham	Early Roman	1	Armitage 2008
Bradley Hill	Late Roman	1 A	Everton 1981
Brancaster 1974	Late Roman	1 J	Jones 1985
Grateley South	Early Roman	2 A	Hammon 2008
Ivy Chimneys	Late Roman	4 A, 1 J	Luff 1999
Keston	Roman	1 A, 1 J	Locker 1999a
Kilverstone	Early (2) and Late Roman (1)	3 A	Higbee 2006
Little Somborne	Late Roman	4 J	Maltby 1978
Lower Cambourne	Roman	1 A	Stevens 2009
Marston Vale	Roman and Late Roman	1 A, 1 J	Strid 2013
Orton Hall Farm	Early Roman	1 A	King 1996
Scole	Late Roman	1 J	Jones 1977
Shell Bridge	Roman	1 A	Harcourt 1999
Stebbing Green	Roman	1 A	Bedwin 1999
Totterdown Lane	Late Roman	1 A	Rielly 2004
Werrington	Early Roman	1 A	King 1988
Wilcote	Roman	1 A	Hambleton 2004
Rural total		*31*	
Urban sites			
Asthall	Late Roman	2 A	Powell, Clark and Serjeantson 1997
Baldock	Early Roman (16) and Roman (1)	11 A, 6 J	Chaplin and McCormick, no date
Derby Racecourse	Late Roman	1 A	Harman, Bramwell and Baker 1986
Elm's Farm	Roman	1 A	Johnstone and Albarella 2002

(Continued)

Table 7.1. List of sites with numbers of ABGs present at each type of settlement (including adults and juveniles; A=adult, J=juvenile, U=unknown age). (Continued)

Site Name	*Phase*	*No. ABGs*	*Source*
Folly Lane	Late Roman	1 A	Locker 1999b
General Accident Site		1 U	O'Connor 1988
Greyhound Yard	Early Roman	1 A	Maltby 1990
Hacheston	Roman and Late Roman	2 A	King 2004
Lant Street	Early Roman (1) and Late Roman (3)	4 A, 1 J	Yeomans 2006
Leicester Shires	Early Roman	2 A	Gidney 1991
Prescott Street	Early Roman	1 A	Rielly 1996
Stonea Grange	Roman	1 A	Stallibrass 1996
Urban total		*35*	
Grand total		68	

trace; Cruess and Dumont 1985) and lack of time for them to accumulate compared to adults, thus juveniles were excluded from further analysis. A more refined classification by age was not possible due to the difficulty in determining the age of dogs once all post-cranial bones have fused: estimation of age via dental wear is much more difficult than in non-carnivorous domesticates, and while methods have been proposed (Horard-Herbin 2000), they are based on a small initial dataset and rarely used by analysts in practice.

7.3.1 Pathological changes

Pathological lesions were present on 48% of all adult ABGs. The specific types found fell mainly into seven categories:

- *Fracture*: Includes both perimortem fractures and signs of healed fractures.
- *Infection*: This includes both signs of infection that had healed prior to death and infection that was still active upon death.
- *Congenital conditions*: This includes chondrodystrophic limbs (abnormally short, twisted limbs resembling those of a dachshund) and absence of the third molar teeth (M3).
- *Osteoarthritis*: This was defined to be fully developed osteoarthritis, not merely its precursors.
- *Excess bone growth*: This includes bone growth of unknown aetiology, typically in the form of exostoses, precursors to osteoarthritis, and bone growth in response to trauma.
- *Fusion between bones (ankylosis)*: This includes ankylosis as a precursor to osteoarthritis, fusions of unknown aetiology and in response to physical trauma.

- *Dental anomalies*: These have been divided into further categories in a separate section due to a wide variation in type and aetiology.

The absence of the third molar presents an interesting issue; it falls into both the congenital and dental pathology categories. The decision has been made, therefore, to include it in the congenital category during analysis (and re-label dental pathology as "Non-congenital dental" for purposes of the analysis). While other dental anomalies *e.g.* malocclusion may be congenital in nature, this cannot be conclusively stated from the secondary data used from the literature.

Nutritional deficiencies and neoplasia are absent from this list, but this may not have any particular significance, due to their status as conditions that are (usually) rare and difficult to unambiguously identify. The diagnosis of osteoarthritis on several of these dogs needs to be treated with caution. Although some authors, particularly from older reports, note any excess bone growth as osteoarthritis, Rando and Waldron argue that in the absence of eburnation (which is pathognomonic of osteoarthritis) at least two other criteria should be met; these include bone growth on the joint surface or margins (osteophytes), pitting on joint surfaces and alteration to the joint contour (Rando and Waldon 2012, 50). Consequently, if an author has described osteoarthritis and it fails to meet these criteria, it will be noted as another issue.

The proportion of each category (Figure 7.1) indicates that fractures and non-congenital dental issues were the most common types of pathological symptoms, whereas congenital conditions and full osteoarthritis were relatively rare. It is possible that osteoarthritis was more common than this total indicates, but the other conditions required to make the diagnosis of osteoarthritis reliable were not identifiable due to taphonomic loss or the absence of sufficient diagnostic skill; another possibility is that the condition was in its early stages and did not subsequently show all the symptoms. It was impossible to chart conditions by aetiology, as in many cases the analyst did not or was unable to propose what the reason behind osteological symptoms may be.

7.3.2 Dental anomalies

Dental pathology fell into six main categories:

- *Ante-mortem tooth loss*: Tooth loss may be caused by trauma or periodontal disease.
- *Abscess*: These are present as localised pockets of infection in the alveolus, which may be caused by periodontal disease or infection from trauma to teeth.
- *Crowding of teeth*: This phenomenon is linked with diminution of the jaw through selective breeding.
- *Congenital absence of the third molar (M3)*: A genetic anomaly that causes the third molar to be absent. It is associated with the inherited diminution of the jaw.
- *Malocclusion of upper and lower toothrows*: Linked to diminution of the jaw from selective breeding.
- *Tooth break*: Caused by trauma, which may originate from a blow or simply chewing on a hard object.

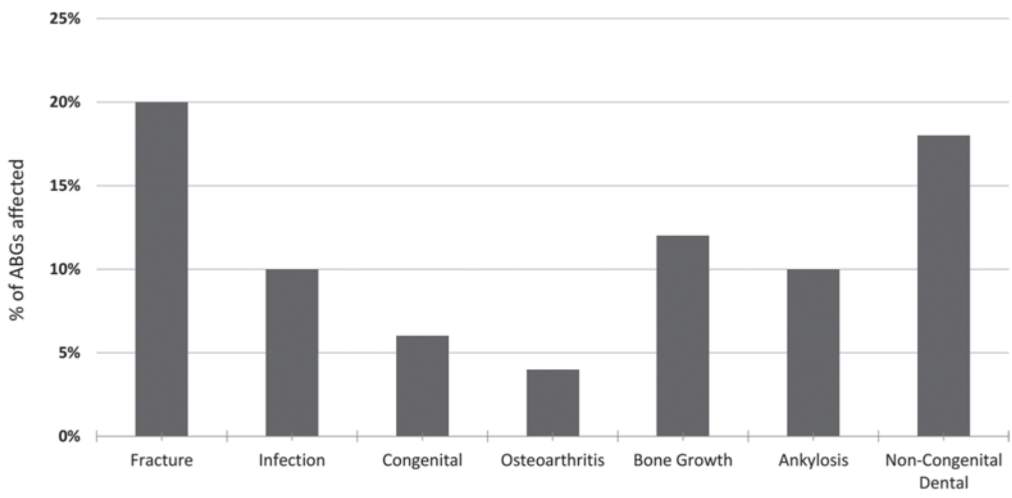

Figure 7.1. Proportion of ABGs with pathology.

Ante-mortem tooth loss and crowding of teeth were the most common dental conditions (see Figure 7.2). Broken teeth and malocclusion were very rare, although their identification may be adversely affected by taphonomic conditions. If a tooth has been broken it may be less likely to survive in the archaeological record. As for malocclusion, a substantial portion of both mandible and maxilla would need to be available for reliable identification. While the possible aetiology for each condition has been outlined, as with other pathological symptoms, it is impossible to speculate on which aetiology may be responsible. It is clear, however, that a small (but significant) minority of dogs suffered from conditions that may be the result of selective breeding, such as malocclusion and crowding of the teeth.

7.3.3 Comparing pathological phenomena with other attributes

It is important to not only investigate the overall rates of pathology, but how they were affected by other variables. This can help uncover the reasons for particular trends and understand their relation to attitudes towards dogs in Roman Britain. To this end, comparing the incidence of pathology with other recorded physical and spatio-temporal attributes may be insightful. The purpose of this is to investigate factors behind variation in pathology in order to then understand why certain conditions occur. For instance, if the only difference seen correlates with size, does this mean that smaller dogs had better welfare because of their diminutive stature? This is a method that has been used successfully with osteological data to investigate the correlation between cockfighting and interpersonal violence (Sykes 2012, 165–166). Only adult ABGs will be included. Juvenile ABGs tend to show very low pathological rates. This may bias the results: many more juveniles were found at urban than rural sites, which would artificially lower the rates of pathology in urban contexts.

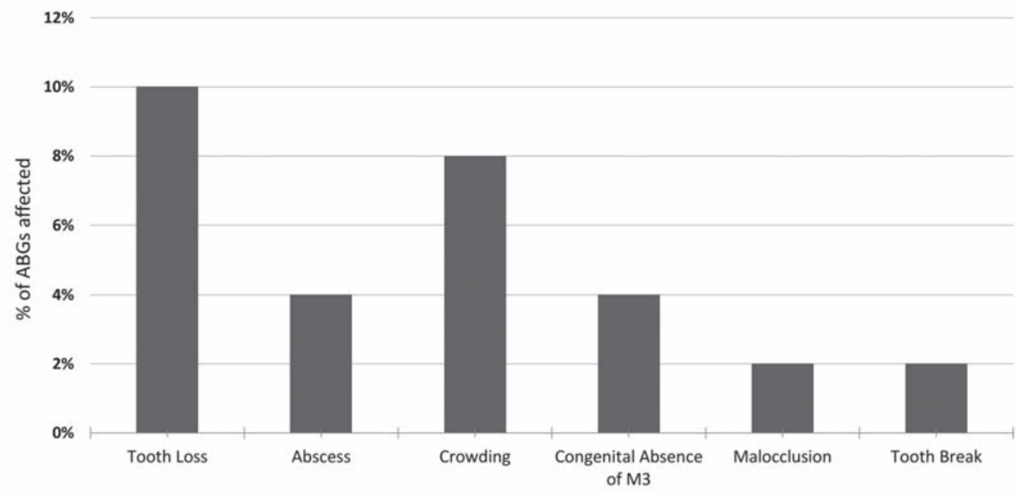

Figure 7.2. Proportion of ABGs with dental pathology.

The variation in overall pathology between a particular attribute will be compared, followed by a more detailed analysis of how it varies according to the types of pathology outlined and their location on the body. This will be quantified as the percentage of all specimens afflicted within the specific category. While the total dataset comprises 49 adult ABGs, some of these do not have particular attributes recorded and were thus not able to be included in all analyses.

7.3.3.1 Pathology and body size

As many of the reports did not comment on the size/estimated withers heights of the ABGs, only 31 cases could be compared from this point of view. The three size categories used by Clark (1995) were adopted for the analysis: <35 cm, 35–50 cm and >50 cm, which were labelled as small, medium and large respectively. There were too few medium sized dogs for analysis, so only small and large specimens were examined.

- Small (17 specimens): 47% showing pathological lesions.
- Large (11 specimens): 55% showing pathological lesions.

Comparing the type and location of pathologically affected bones in small and large dogs reveals interesting differences. Small dogs are considerably more prone to dental anomalies, particularly crowded teeth in the jaw and congenital absence of the M3 tooth (Figure 7.3). Large dogs show a higher rate of conditions associated with excess bone growth and osteoarthritis: these are more commonly found in the trunk and paw (Figure 7.4). Although the incidence of pathological lesions in the skull is lower than in other skeletal parts, it is twice as common in large individuals as small dogs. Fractures are present only in large dogs.

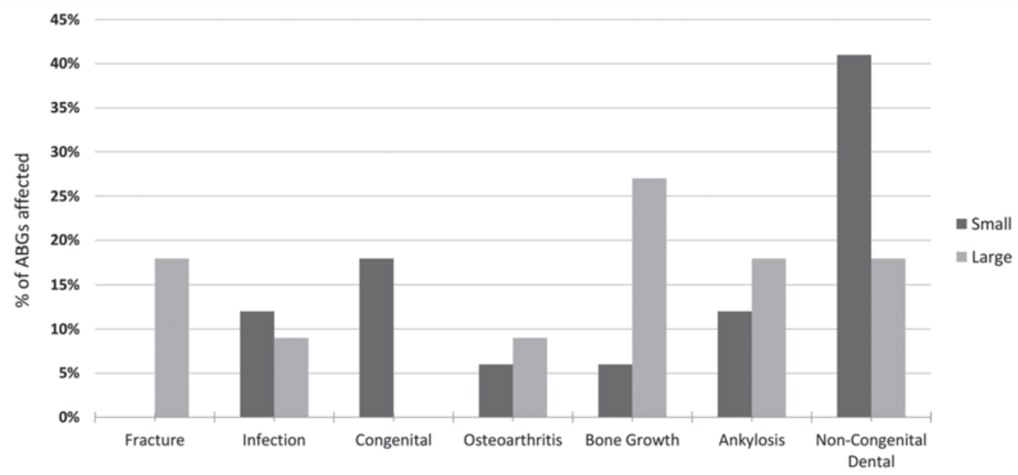

Figure 7.3. Proportion of pathology in small and large dogs by type.

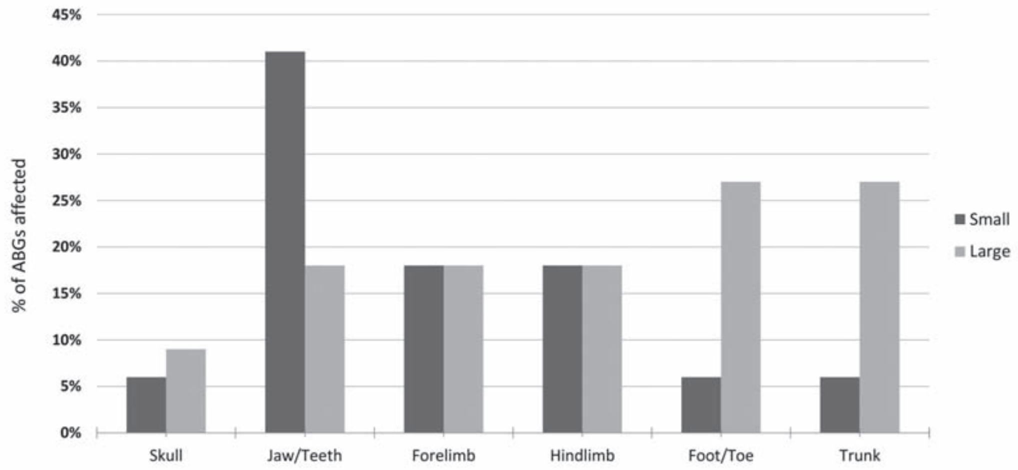

Figure 7.4. Proportion of pathology in small and large dogs by location.

7.3.3.2 Pathology and archaeological phase

The chronology of the results varied wildly in their accuracy. Some ABGs could not be phased at all due to various reasons: lack of space in site report, particularly in small or multi-period works, lack of phasing data, and issues in the report itself such as unclear phasing. Given the relatively small well-dated dataset (38 ABGs) left for division into standardised phases, and the fact that many more sites had been originally categorised in this way, it was decided to divide the results into two main chronological

groups: Early and Late Roman. Any further categories, such as Middle Roman, were not considered viable.

The date dividing the Early and Late Roman categories was judged to be the beginning of the 3rd century. This date correlates roughly with political turbulence in the Roman Empire more significant than anything in the preceding two centuries, which eventually led it to fracture into two separate administrative divisions (Goodman 2012, 257–258). It also allows for the division of the many results that were divided into phases by century, as fewer dates spanned the 2nd–3rd centuries than the earlier 1st–2nd and later 3rd–4th. Phases that overlapped both the Early and Late Roman categories were assigned to the general Roman category if they overlapped both equally and significantly, but if they covered only 20–30 years of one category and the entirety of the other, they were assigned to the predominant phase.

The results were as follows:

- Early Roman (23 specimens): 52% showing pathological lesions.
- Late Roman (16 specimens): 38% showing pathological lesions.

The types of pathology vary considerably between the two phases, producing slightly unusual results (Figure 7.5). Infection was non-existent in the Early Roman phase whereas fractures were very rare in the Late Roman period. This is a slightly inconsistent result: if fractures were happening at a higher rate in the Early Roman period, surely some of these fractures would have led to infection? This indicates that it is important to be wary of results originating from a small dataset. Aside from this, the only other differences apparent between the two periods are a higher rate of pathology in the trunk and skull in the Early Roman period, while pathological lesions in the forelimb and paw are more common in the later years of Roman Britain. The incidence of non-congenital dental pathology is also much higher in the Late Roman period. There is a possibility that, as dental pathology is more prevalent in small dogs, this phenomenon is directly correlated to the increase in the number of small dogs across the Roman period.

7.3.3.3 Pathology and site type

Investigating differences in attitudes towards dogs in different types of location is a key area for analysis, and fits well with prior zooarchaeological work on the differences in food provisioning between urban and rural locations. Although there are different types of sites even within these meta-divisions, the data are insufficient to investigate variation in pathology between rural farmsteads and villas, for instance. As only two of the 49 adult ABGs came from military sites, which are too few for analysis, they have been excluded in order to help focus on the better represented urban and rural locations.

- Urban sites (27 specimens): 56% showing pathological lesions.
- Rural sites (21 specimens): 38% showing pathological lesions.

The detailed results (Figure 7.6) indicate a higher incidence of fractures in dogs at urban sites which are also the only site type to show any instances of infection. Dogs from

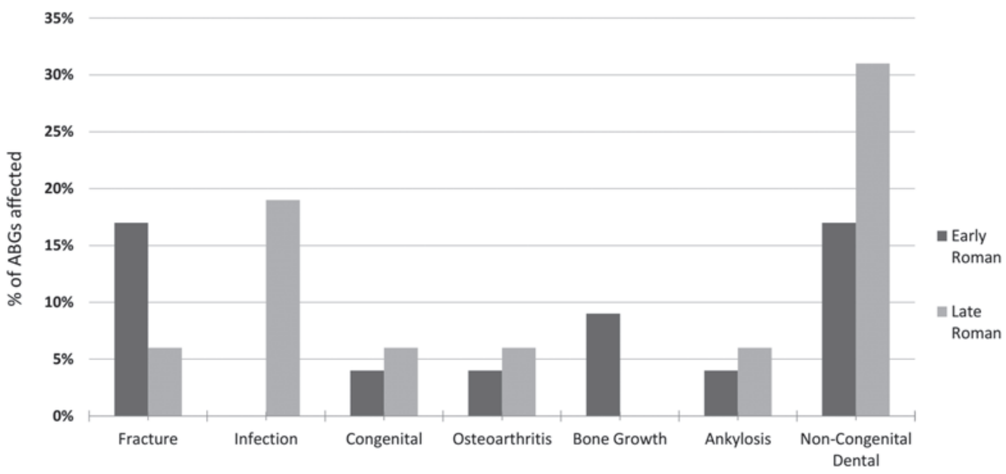

Figure 7.5. Proportion of pathology in different phases by type.

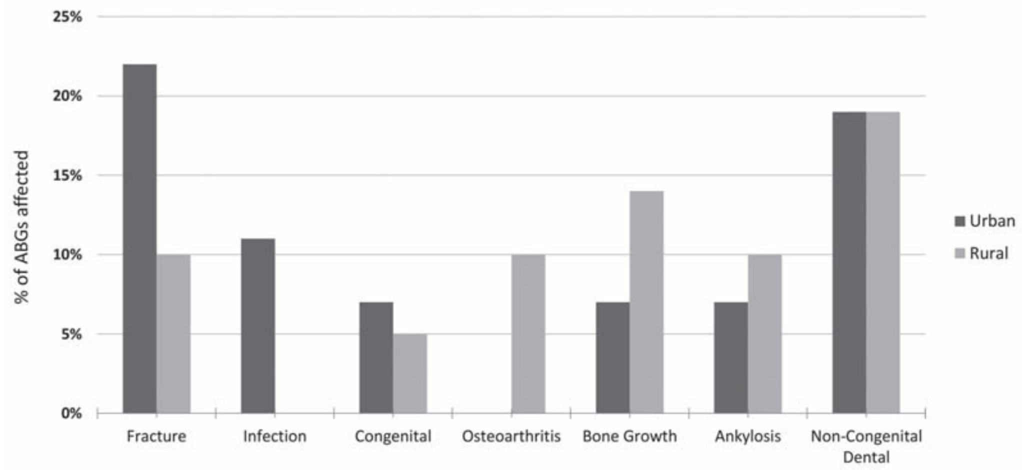

Figure 7.6. Variation in pathology between urban and rural dogs by type.

urban locations also display a much higher rate of pathological changes in the hind limb, and more modest increases in pathological lesions in the skull and foot bones (Figure 7.7). Upon further investigation, all of the variation in fractures between rural and urban sites may be attributed to a higher rate of fractures in the femur in urban specimens. On the other hand, rural dogs have higher rates of excess bone growths and ankyloses combined with a greater degree of pathological symptoms in the trunk; it is also noteworthy that osteoarthritis is only present in rural ABGs. The occurrence of dental anomalies is fairly similar across the two site types.

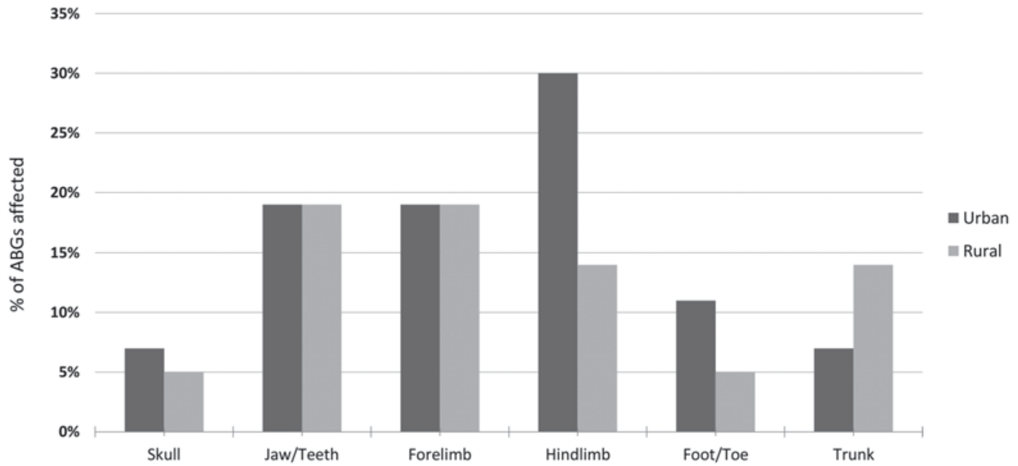

Figure 7.7. Variation in pathology between urban and rural dogs by location.

7.3.4 Multivariate analysis

While it is evident that all of the previously discussed attributes have some influence on pathological changes in dog skeletons, it is less apparent if their contributions are equal. Some of the attributes have a degree of overlap. Of the ABGs identified to body size, 69% were small and 25% large on urban sites: contrasted with 53% of rural ABGs being large and only 31% small. This may affect the distribution of pathology on both types of sites. Correspondence analysis has therefore been undertaken to attempt to disentangle the different variables from one another.

The correspondence analysis was undertaken to compare all three attributes used as variables (body size, group phase, site type) against the prevalence of the type of pathological lesions (Figure 7.8). The resulting two main axes largely correspond to the Early–Late Roman subdivision (axis 1, encompassing 58% of the total variance) and the rural–urban dichotomy (axis 2, encompassing 23% of the total variance).

The distribution of data points within the plane defined by these two axes indicates that chronic conditions (excess bone growth, ankylosis and osteoarthritis) were more closely associated with rural sites, large dogs and the Early Roman period. Congenital conditions and infection on the other hand were more closely associated with small dogs and the Late Roman period, and to a lesser degree urban sites, while non-congenital dental conditions were particularly closely associated with these variables; indeed, they displayed the closest connection. Fractures did not seem to be particularly associated with any of the three attributes (body size, site type, chronology), but were remarkably separated from the group of chronic lesions. The analysis first indicates that several disparate attributes have associations with one another, which subsequently renders attempting to disentangle the aetiologies responsible for particular types or locations of pathological symptoms very difficult. It is unknown, when it comes to ankylosis, whether the rural sites, large dogs or Early Roman period were of particular importance over the other variables.

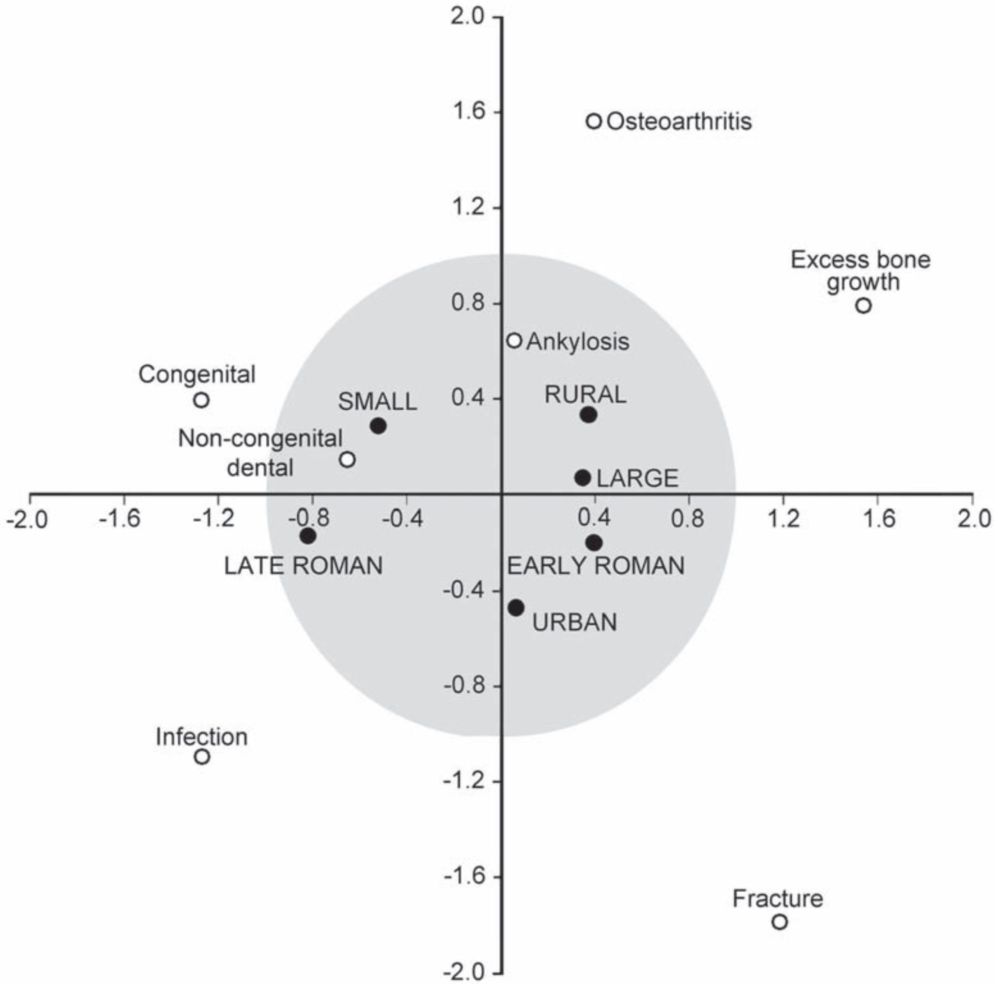

Figure 7.8. Correspondence analysis of site type, size and time period against pathology type.

7.4 Discussion

7.4.1 How prevalent was abuse?

A key question to consider when investigating human–animal relationships, particularly from an osteological perspective, is the prevalence of abuse. This is particularly relevant in the case of dogs, animals who often live in close contact with humans. However, investigating abuse must be done with caution: it is easy to attribute all fractures and trauma noted to abuse when there may be many different causes. Criteria that may be used for differentiation have been outlined by Binois *et al*. (2013): abuse is more likely in animals that have multiple fractures in different stages of healing or a predominance of fractures in the head and trunk.

Within this dataset, 15% of dogs had at least one fracture. The location of these fractures is fairly evenly spread across body parts, which suggests a particularly high prevalence of abuse was, in the main, unlikely. However, it is possible that there is variation along the lines of the physical and spatiotemporal attributes discussed. There are higher rates of skull/trunk injuries in large dogs and those from the Early Roman period, so it is possible that these dogs were more likely to suffer abuse than smaller individuals or those from the Late Roman period.

In terms of the criteria for abuse, there are only two ABGs that are anywhere near meeting both: the ABGs from the Elm's Farm and Grateley South sites. The former has multiple fractures in the limbs only (Johnstone and Albarella 2002), representing two separate incidents. As the dog had no indication of injury in the head or trunk, it is therefore possible that they were instead the result of two accidents. On the other hand, the Grateley South ABG has many lesions across the skeleton: a metatarsal and several vertebrae show signs of either a healed fracture or infection, while two ribs were fractured earlier in life (Hammon 2008). If the former could be re-examined, and a more conclusive statement made about whether they were healed fractures or infections that occurred as a result of trauma, there is a strong likelihood that this dog was abused, considering at least two separate incidents appear to have occurred.

7.4.2 Welfare

Another important consideration is the physical welfare of dogs in the Roman world. This is a time before advanced veterinary care and antibiotics, which would have favourably affected the welfare of dogs aside from anthropogenic factors. Around one in seven dogs suffered from infection or osteoarthritis at some stage in their lives, which would have resulted in considerable pain. Although the veterinary literature considers infection and even its impact on bone, it is written for modern practitioners with advanced therapy such as antibiotics readily available. It is therefore less well-placed to discuss longer-term implications of inability to treat infection on the animal's welfare and quality of life. In the case of Romano-British dogs, it is likely that if infection was not cleared by the immune system early on it may have persisted for years and even caused the death of some dogs, either sooner or later. Chronic osteomyelitis is described to present pain and lameness in the animal (Nunamaker 1985) and on the bone as *periostitis, involucrum* formation and sinus tracts (Pineda *et al*. 2009, 82). Acute osteomyelitis is more difficult to detect than chronic, and changes to the bone may be very subtle (Baker and Brothwell 1980, 68), therefore proving more difficult to notice. This has two implications: the first that the true rate of infection may be higher than what the data indicate, the second is that the infections recorded are thus likely to be chronic and potentially cause significant impairment and pain.

One ABG in particular strongly indicates a seriously reduced quality of life as a result of injury. The ABG from Stonea Grange suffered only one fracture of the femur. However, the fracture failed to heal properly and the dog may have been in considerable pain as a result of the fracture's nature and consequential infection. Indeed, it is likely the dog eventually died as a result of blood poisoning from the infection (Stallibrass 1996, 608). Overall it appears that some of the dogs represented

by these ABGs experienced a significantly reduced quality of life as a result of chronic infection. Only one specimen displays signs of a less severe, healed osteomyelitis: an ABG from Asthall that shows a healed infection on the metacarpal, which appears as a small pit (Powell *et al*. 1997).

When examining lesions that may have caused the dog to suffer, the key question is whether its owner/s could have either prevented it from happening or cared for it. Were some injuries, if not caused by humans, aggravated by their neglect? It is essential to consider to what extent Romano-British people were capable of treating injuries. While fractures may have been set or splinted in the wider Roman Empire (Udrescu and Van Neer 2005, 30–31), this cannot be investigated further in this dataset due to the secondary nature of the data. In the case of infection, Roman doctors could do little to treat it (Salazar 2000, 33).

Many cases of excess bone growth and ankylosis found in the dogs may be linked to age. Although many are not sufficiently advanced to be strictly classed as osteoarthritis, some appear to be precursors: the Greyhound Yard ABG has widespread growth on the vertebrae and limb articular surfaces, indicating onset of severe osteoarthritis (Maltby 1990, 63–64). However, it is important to be cautious and not link all excess bone growth automatically with age, as some may be the result of injury such as ligament trauma. When extraneous bone growth accompanies infection, it may be indicative of injury. Unfortunately, further analysis is not possible: the lack of relevant detail is a significant disadvantage in using secondary data.

It is important to consider the impact of increased physical stress as a result of greater bodyweight, on bone growth and fusion. There is currently discussion in regards pathology in cattle feet: whether exostoses and lipping are age-related or linked to physical stress (which may be increased in larger animals; Bellis 2014; Johannsen 2005). Even if the discussion were conclusive, however, this may not apply to the entire canine skeleton. Baker and Brothwell (1980, 100) speculate that osteosarcoma may possibly be caused by stress on the limbs of larger animals <30 lbs. A considerably higher rate of excess bone growth and moderately higher rate of ankylosis in large dogs over smaller specimens lends support to physical stress as a contributing factor, but this is far from conclusive. Overall, excess bone growth seems to have affected large dogs more widely and adversely than small dogs, but this type of bone growth is not particularly conclusive about welfare beyond this due to potentially diverse aetiologies. Lack of primary data is a hindrance in this case as well. However, excess bone growth that is linked with osteoarthritis or its onset may be indicative of the animal being in pain (MacKinnon and Belanger 2006, 42).

7.4.3 Overall implications for human–dog relationships

Given the lack of evidence of anthropogenic pathology in Romano-British dogs, the data indicate that human–dog relations were not poor. Conflict and neglect, on the whole, would have been characterised by more evidence of intentional harm and a continual lack of basic assistance. Due to the absence of data on the rendering of assistance, the social relationship cannot be commented on beyond "not poor" in terms of welfare. It is the rendering of further assistance that could indicate the difference

between indifferent and more caring, potentially personal relationships. There are also many aspects of human–dog relationships that the data cannot illustrate: a particularly important example is the way that the dogs died. Only a couple of ABGs show any indication, usually in relation to a recorded pathology (*e.g*. the aforementioned Stonea Grange ABG, which had a severe leg infection which did not heal by the time of death: thus being a probable cause).

The previous comparison between types of pathological lesions and other attributes do offer clues for further investigation. For instance, the difference between rates of pathological specimens in urban and rural sites indicates that uses of and/or attitudes toward dogs may have been different between these two forms of settlement. However, the differences between urban and rural sites indicate that any difference in the human–animal relationship between the two site types was, at most, eliciting changes in the rate of fractures and subsequent infection, mainly in the femur (which included both healed and unhealed fractures at the time of death). It is likely, therefore, that the variability was not linked to different attitudes to dogs at all and arose as a result of accidents sustained in an urban environment (Roman cities were described in classical sources as hazardous; de la Bédoyère 1992, 63): this is further suggested by the lack of trunk pathologies. The main difference between urban and rural sites appears to be the type of dogs kept (more small dogs in urban environments), not their treatment. A preference for smaller dogs in towns, however, may have been part of an effort to minimise dog–human conflicts.

The size of dogs appears to be another attribute that shows variation more due to factors beyond human attitudes and interaction. In this case, it is the differing physiology between small and large dogs: the greater potential for dental anomalies in the former due to jaw diminution, and the greater potential for skeletal growth due to greater strain on the bone resulting from excess bodyweight. Yet there may be another component. Larger dogs still have higher pathology rates in the trunk, which may be due to a slightly higher rate of abuse or more accidents sustained while working in a rural setting.

While it needs exploring further, there appears to be some change in the rate and type of pathological lesions in dogs through time. Overall, the rate appears to have decreased significantly from the Early to Late Roman occupation. The shift in anatomical location is also of interest: the decrease in skull and trunk pathology while the overall rate decreases may be significant. It is possible that human–dog relationships improved through time, a trend inseparable from urbanisation.

7.5 Conclusions

In reviewing the pathological conditions in dog ABGs in Roman Britain, it appears that the level of physical abuse of dogs was relatively low. The physical welfare of dogs is unlikely to have been worsened significantly by humans and it is possible, if unascertainable, that some fractures may have been splinted. However, due to lack of advanced veterinary care, a sizeable minority of dogs suffered from chronic pain throughout their lives from either infection or osteoarthritis: a few particularly bad cases may have necessitated care from humans.

Dog size and spatiotemporal attributes all affect the manifestation of pathology, but for different reasons. Size is due to physiological factors and potentially differing human attitudes to large and small dogs. Chronological phase is less clear, but could indicate improvement in human–dog relationships throughout the Roman occupation while site type may be linked with the risk of accidents in towns and/or the preference for smaller dogs on urban sites and large dogs on rural. The multivariate analysis indicates that while all were contributing factors to the distribution of various pathological lesions, they were of variable importance. Nonetheless, fully disentangling these factors from one another as is impossible, as is pinning down a specific cause for variation. On the whole, however, pathological evidence indicates the human–dog relationship in Roman Britain to be relatively benign. To explore this problem more would require much more data and integration with other sources, particularly classical texts on dogs and dietary analysis using stable isotopes. The former in particular may offer valuable insights into other aspects of dog welfare that are impossible to investigate through physical remains alone.

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8. Four Equestrian Burials from the Avar Cemetery at Vienna Csokorgasse, Austria: The Health of Horses and Dogs

Henriette Baron

In 1976 and 1977, construction work in the area of the Csokorgasse in Vienna's 11th district necessitated the excavation of a large Avar cemetery: 705 burials of the 7th and the 8th centuries AD were discovered. In the southern periphery of the cemetery, four richly furnished burials of horsemen were unearthed (burials 650, 690, 692, 693). Among other animal finds, they contained remains of horses and dogs. These burials date to the Late Avar Periods II and III (*c.* 730–800 AD). The palaeopathological analysis of these skeletons unveiled some pathologies that could relate to the respective uses of the animals. Some of these animals already suffered from a variety of afflictions, though not all of these handicapped them to a degree that would have affected their use by humans.

8.1 Introduction

In 1976–1977, construction work in the area of the Csokorgasse in Vienna (11th district) necessitated the rescue excavation of an extensive Avar cemetery. The complete cemetery comprising 705 burials was excavated under the direction of Ludwig Streinz on behalf of the Historical Museum Vienna (today called Wien Museum). The majority of the archaeological finds still await archaeological examination. The animal bone material was subject of my PhD thesis (Baron 2018). Recently, Falko Daim and Ludwig Streinz have worked out the chronological system of the cemetery, to be included in that monographic evaluation (Baron 2018). The cemetery was continuously used from the second quarter of the 7th century (Early Avar Period II) until the end of the 8th century (Late Avar Period II and III). The latest period is marked by four conspicuously rich burials in the south of the cemetery that contained horses and dogs. Equestrian graves are not unusual in this time period. According to Bede (2012, 43) approximately 6000 Avar horse burials have so far been excavated. However, only few Avar dog burials are known from different sites in Austria, Slovakia, Hungary and Serbia (Baron 2018). As was common in this period, the inhumation graves are laid out in a west–east orientation and were endowed with a variety of grave goods. Amongst these, animals and animal parts were abundant.

Animal bone finds were noted in 491 of the 705 burials (70%). In most cases they can be generally categorised as food remains, even though at least a part of the food

Table 8.1. Vienna Csokorgasse. Sex, age and body size of the horses and dogs presented in this paper.

Burial no.	*Species*	*Sex*	*Age (years)*	*Withers height (cm)*
650	horse	female (?)	7	143
690	horse	male/gelding (?)	8–9	139
692	horse	male	4–4.5	138
693	horse	male	8–9	144
650	dog	male	1.5–2	65.5
690	dog	male	> 1.5–2	63.7
693	dog	male	> 1.5–2	64

offerings carried additional meanings (Kroll 2012/2013). For more details on these see my other articles (*cf*. Baron, this volume) or the monograph (Baron 2018). This paper deals with pathologies observed on the horse and dog skeletons from the four equestrian burials (650, 690, 692 and 693). As in each case the dog and horse were buried together, they seem to represent a functional unit. Hence, an attempt is made to deduce some information regarding the potential lifetime roles of these animals. Most lesions observed on the horse skeletons from the Avar cemetery at Vienna Csokorgasse confirm analogous observations made elsewhere. The marks of utilisation differ at the most in their intensity, as well as in terms of the care dedicated to the animals. In order to grasp these factors, it would be worthwhile to scrutinise whether different find assemblages show varying correlations between pathologies (or their degrees) and the age of the respective horses. This all-inclusive review, however, is beyond the scope of this paper. The observations of skeletal ossification and features relevant for sexing these animals, as well as the inclusion of the healthy horse identified in burial 692 and the dog described from burial 650, are aimed to make these finds usable for future meta-analyses.

8.2 Material and method

8.2.1 The equestrian burials 650, 690, 692 and 693

The four equestrian burials – 650, 690, 692 and 693 – are located in close proximity in the very south of the Avar cemetery. Each of the four burials contained a complete horse skeleton. Three graves (650, 690 and 693) each yielded the skeleton of a large adult male dog. In burial 692 only a dog tibia was found, and in burial 650 additional remains of a puppy were identified in the shaft of the grave. This puppy, as well as another puppy from a child's burial (462) and the tibia from burial 692, are not detailed here, as they yielded no palaeopathological information.

A late mature to senile man rested in burial 650. Burials 692 and 693 also contained adult men. In burial 690 three persons were laid to rest: two children of about 6 and 8 years (apparently placed into the burial subsequently) and an adolescent of 13–15 years of age. Judging by their grave furnishings, the adult men and the adolescent

seem to have been high-status individuals. For a detailed archaeological description of these burials, see Streinz (1977).

The horse was placed left of the buried man, separated by a wooden wall or by the coffin of the human. The dogs seem to have been consistently placed in the area of the horses' hind legs. The burial situation is not always clear as these richly furnished burials were robbed, presumably shortly after interment. This often led to a dislocation of finds. An extreme displacement occurred in the case of the horse from burial 690. Large parts of its left forelimb, *i.e*. scapula, humerus and radius/ulna were found in the neighbouring burial no. 689 where an adult woman had rested. However, skeletal elements of the foot connecting distally from these long bones (*i.e*. carpalia, metacarpalia and phalanges), were still found in the original burial 690. This shows that both burials 689 and 690 were robbed at the same time and that the horse was still articulated to a certain degree when its skeleton was disturbed. The dog found in burial 690 also seems to have been removed and thrown back into the grave again: its skeleton was found displaced in the shaft of the burial. The horses were equipped usually with saddles, stirrups and full harness. In burial 650 both the horse and dog were adorned with a little bell. A cut-mark on the left cheekbone of the horse in burial 690 certainly stems from the removal of its ornate halter by means of cutting the leather (Figure 8.3a).

8.2.1 Ageing

The most detailed means of estimating the age of horses is the dental development, because not only tooth eruption but also the degree of abrasion can be taken into account. Until the age of 4.5 years, the eruption first of the deciduous and then of the permanent teeth can be interpreted. For older individuals of up to eleven years the condition of the occlusal surfaces of the incisors, as well as the shape and depth of an enamel invagination in these, can be consulted. The latter disappears in the first inferior insisors by the age of six years, in the second inferior incisors with seven and in the third inferior incisors with eight years. For the respective superior incisiors about three years later (Vollmerhaus, Roos and Knospe 2002). For even older individuals the shape of the abraided teeth can be taken into account. They change from horizontally oval (6–12 years) to rounded (12–17 years) and triangular (18–24 years) towards a vertically oval shape (24–30 years, Sambraus 1991, 48). Observations on the epiphyseal fusion were used as complementary evidence (Habermehl 1975, 48ff.).

In dogs, the permanent dentition is completed at a young age – about six months (Habermehl 1975, 159). Furthermore, suggested time frames for the skeletal ossification vary considerably (Spahn 1986, 23–24 tab. 10). It is supposed to be completed by the age of 1.5–2 years. Hence, only the degree of dental abrasion can be taken into account for animals with ossified skeletons and a complete dentition. This is, however, strongly dependent on the diet of the individual.

8.2.2 Sexing

The sexing of horses can be carried out by means of the teeth and the pelvis. Canines appear primarily, but not exclusively (Pucher *et al*. 2006, 485) in male individuals.

They are generally larger in males. Their presence points to a male sex, but should be confirmed by observations on the pelvis if complete skeletons are available. Stallions are supposed to have a marked *tuberculum pubicum dorsale*, which leads to a generally rounded shape of the *ramus acetabularis ossis pubis*. Mares, however, have no *tuberculum pubicum dorsale*. Hence, the *ramus acetabularis* of the pubic bone is flat. Geldings are supposed to show intermediary features, depending on the age of castration (Ambros and Müller 1980, 21). Furthermore, the pelvis of a mare is generally more spacious than the pelvis of a stallion (Nickel and Schummer and Seiferle 2004).

The adult dogs could be unambiguously sexed because all of the skeletons (burials 650, 690 and 693) had a baculum, the bone of the penis.

8.2.3 Withers height calculations

For the withers height calculations of horses, the factors proposed by E. May (1985) were used. The withers heights of the dogs were estimated using the coefficients suggested by R. A. Harcourt (1974) and F. Koudelka (1885).

8.2.4 Pathologies

The pathological lesions were recorded in a descriptive manner. Apart from general overviews (von den Driesch 1975, Baker and Brothwell 1980, Bartosiewicz and Gál 2013), some more specialised studies were used (Daugnora and Thomas 2005; Bendrey 2007; Ambros and Müller 1980; Csippán and Daróczi-Szabó 2008; Bartosiewicz and Bartosiewicz 2002).

Complete horse skeletons are often available for analysis because, on the one hand, these animals were usually not dismembered in order to eat them, and on the other, because complete horses were buried in many time periods and cultures for various ritual reasons. Accordingly, the state of palaeopathological research is quite good for this species. Literature on dog palaeopathology is somewhat scarcer and more general pathology studies have to be consulted, as dogs are not as often interred in the company of their owners compared to horses.

8.3 The horses

8.3.1 Burial 650

8.3.1.1 Completeness, sex, age and withers height of the horse

Except for some tarsalia and carpalia, the horse skeleton is complete, but it is partially highly fragmented. Both mandibula and maxilla carry canines. The *ramus acetabularis* of the pubic bone, however, is cranially very flat and does not show the rounded profile typical for stallions, nor a tubercle. The pelvis is wide. Hence, an interpretation of this horse as a mare seems more likely. According to the epiphyseal fusion (the apophyses of the pelvis and vertebrae are fused, the gap still visible) and the development of the incisor surfaces, an age of death of about seven years seems likely. The calculated withers height is 143 cm (±8 cm).

Figure 8.1. Vienna Csokorgasse. Horse from burial 650, os incisivum with a sulcus on both sides (greatest breadth of snout [45] 75.1 mm). Measurements after von den Driesch 1976.

8.3.1.2 Special features

Approximately in the middle of the *processus nasalis* of the os incisivum, a small sulcus is visible (Figure 8.1). The horse unearthed in burial 693 shows a similar sulcus. According to W. Pérez and E. Martin (2001), this is presumably caused by a certain functional interaction between the *musculus lateralis nasi* and the *cartilago nasalis accessoria medialis*. I do not know of any information concerning the aetiology and incidence of this phenomenon in pre- or protohistoric horses. Furthermore, the first premolar is missing both in the maxilla and mandibula.

8.3.1.3 Pathologies

The skeleton shows a variety of pathological alterations (Figure 8.2). The second premolar of the right maxilla is slightly abraded rostrally, presumably caused by the snaffle. The alveolus underneath the left third inferior premolar is distended buccally, presumably in consequence of an inflammation of the dental roots (Figure 8.2b). The left third inferior molar has an uneven occlusal surface which forms a spike aborally. The antagonist molar in the maxilla, however, does not show any signs.

The muscle or tendon insertions on the atlas are partially ossified. Dorsally it carries exostoses and on the inside of the *arcus ventralis* grinding marks caused by the *dens axis* are visible (Figure 8.2c). The vertebrae thoracicae 11 to 16 began to fuse in the area of the *processus spinosi* (Figure 8.2d). The 18th thoracic vertebra carries exostoses on the dorsal rim of the *processus mamillaris* (Figure 8.2e). The first three vertebrae lumbales have also formed exostoses on the rim of the caudal articular surface (Figure 8.2f). The latter shows a tendency to fuse with the fourth vertebra lumbalis, which again begins to fuse with the fifth. The last vertebra lumbalis carries exostoses on the cranial articular surface and has caudally formed a small sulcus on the left side. The formation of exostoses up to the fusion of the thoracic and lumbar spine (*spondylosis ankylosans*) occurs often in older riding horses, rarely also in young ones. This condition was met in 42% of the Avar Horses included in a study by C. Ambros and H.-H. Müller (1980, 80–81). These authors do not think that such animals suffered considerably.

Two costal cartilages were fractured in life and healed with dislocation. The left latero-ventral surface of the left scapula displays lesions, which could perhaps be pseudopathologies due to soil circumstances (Figure 8.2h). There is a small hole in the

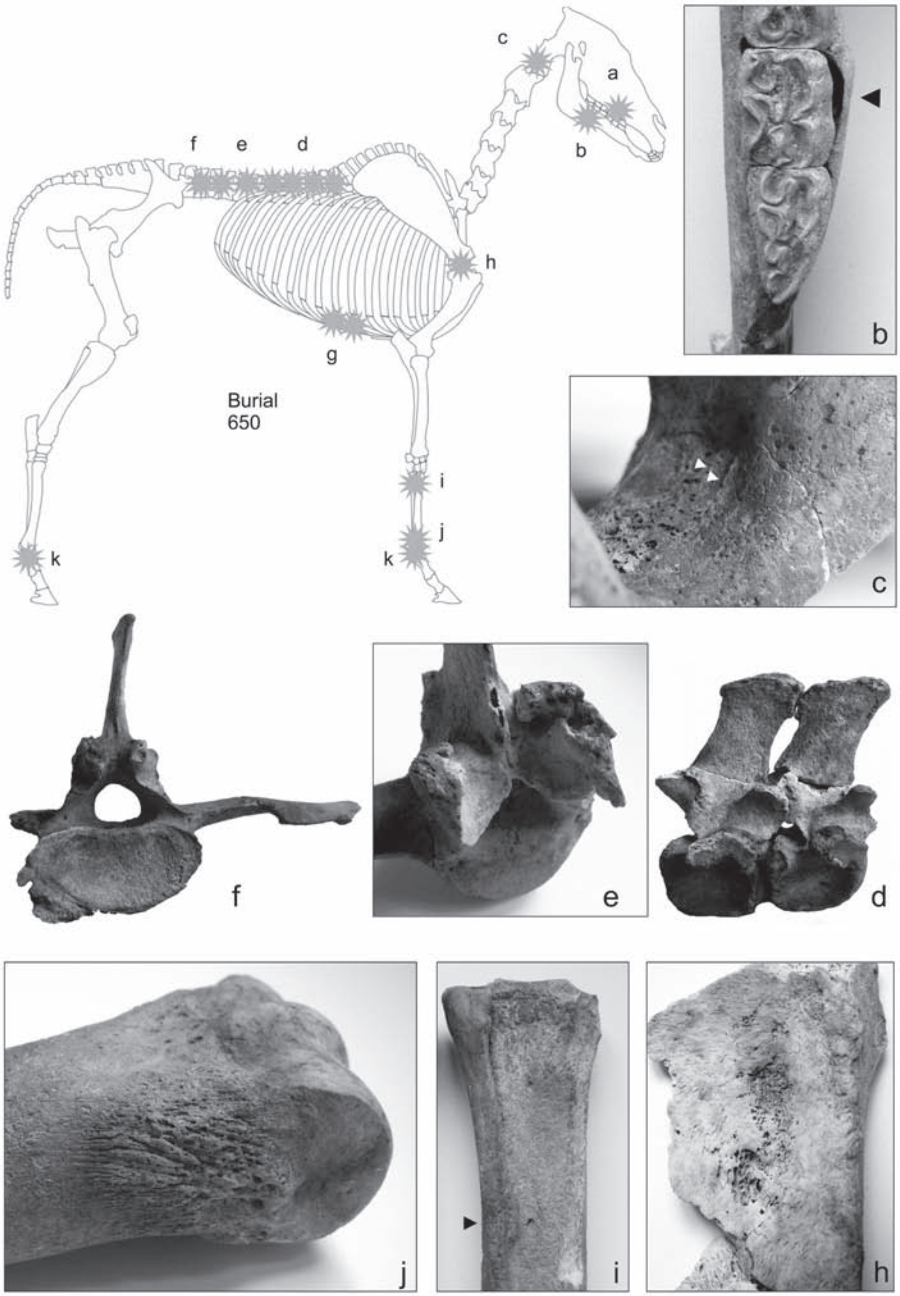

Figure 8.2. Vienna Csokorgasse. Horse from burial 650, probably female, ca. *6–7 years old. a) right P^2 sup. (not pictured); b) alveolus of the left P_3 inf. (LP_3=27.4 mm); c) atlas (GL=103.7 mm); d) thoracic vertebrae; e) 18th vertebra thoracica (BFCr=59.9 mm); f) vertebra lumbalis; g) cartilago costae (not pictured); h) left scapula (KLC=67.7 mm); i) right metacarpus (Bp 50.4=mm); j) left metacarpus (GL=235.9 mm). Measurements after von den Driesch 1976.*

articular surface of the right scapula, probably symptom of an arthritis (Daugnora and Thomas 2005, 69). The left metacarpus shows medio-distal a roughness, which might be due to a periostitis, an inflammation of the *periosteum* (Daugnora and Thomas 2005, 69; Figure 8.2j). The medial splint bone (right metacarpus II) is fused to the metacarpus III (so-called *desmoiditis ossificans ligamentum interosseum*, Figure 8.2i). Three of the four horses display such alterations. They could be caused by a use of the animals on very hard soil, which can set the bones in motion against each other. Even though the aetiology is yet unclear, often physical strain is assumed as a cause (Bendrey 2007; Daugnora and Thomas 2005, 69). Two proximal phalanges (presumably one anterior, one posterior) show chafed areas on the proximal articular surface. Such lesions are also visible on the medial and lateral rims of the condyles of the left metatarsal. Chafings like this are classical symptoms of arthritic overstrain: the cartilage is abraded and the joint inflamed (Daugnora and Thomas 2005, 69).

8.3.2 Burial 690

8.3.2.1 Completeness, sex, age and withers height of the horse

As major missing elements were found in burial 689, this horse skeleton is almost complete. The torso as well as the skull, the spine, both femora and the scapulae were so heavily damaged that it was not possible to reassemble them. This animal, too, has superior as well as inferior canine teeth. The pelvis is delicate and rather narrow, the *ramus acetabularis* of the pubic bone is rather flat than rounded. However, it is dorsally damaged and it is not discernible whether a *tuberculum dorsale* existed. Perhaps this individual was a gelding. The animal has reached an age of approximately eight to nine years. All long bone and cranial vertebra epiphyses are fused, the ilium apophyses and most of epiphyses in the caudal vertebrae are still unfused. The occlusal surfaces of the incisors match the stage of an animal of eight to nine years. The calculated withers height is 139 cm (±8 cm).

8.3.2.2 Pathologies (Figure 8.3)

Among the non-pathological modifications, cut marks were observed on the left arcus zygomaticus of this animal (Figure 8.3a) whose peri- or post-mortem origin is impossible to establish. A hole is located in the area of the *protuberantia occipitalis* which could result from a strong blow to the back of the head (Figure 8.3b). Independently of the unhealed trauma osteophytes had formed above this hole towards the *crista nuchae*.

The *arcus ventralis* of the atlas shows grinding marks caused by the *dens axis* (Figure 8.3c). The *processus articulares caudales* of the 18th thoracic vertebra display exostoses as well as a tendency to fuse with the adjoining lumbar vertebra (*spondylosis ankylosans*), which, however, is poorly preserved in this individual.

A thickened muscle insertion, not really pathological in nature, can be detected on the medio-palmar side of the left radius. The fusion line of the medial splint bone of the left metacarpus is marked by light osteophytes. The same applies, to an even stronger degree for the medial splint bone of the right metacarpus (Figure 8.3f, bilateral *desmoiditis ossificans ligamentum interosseum*).

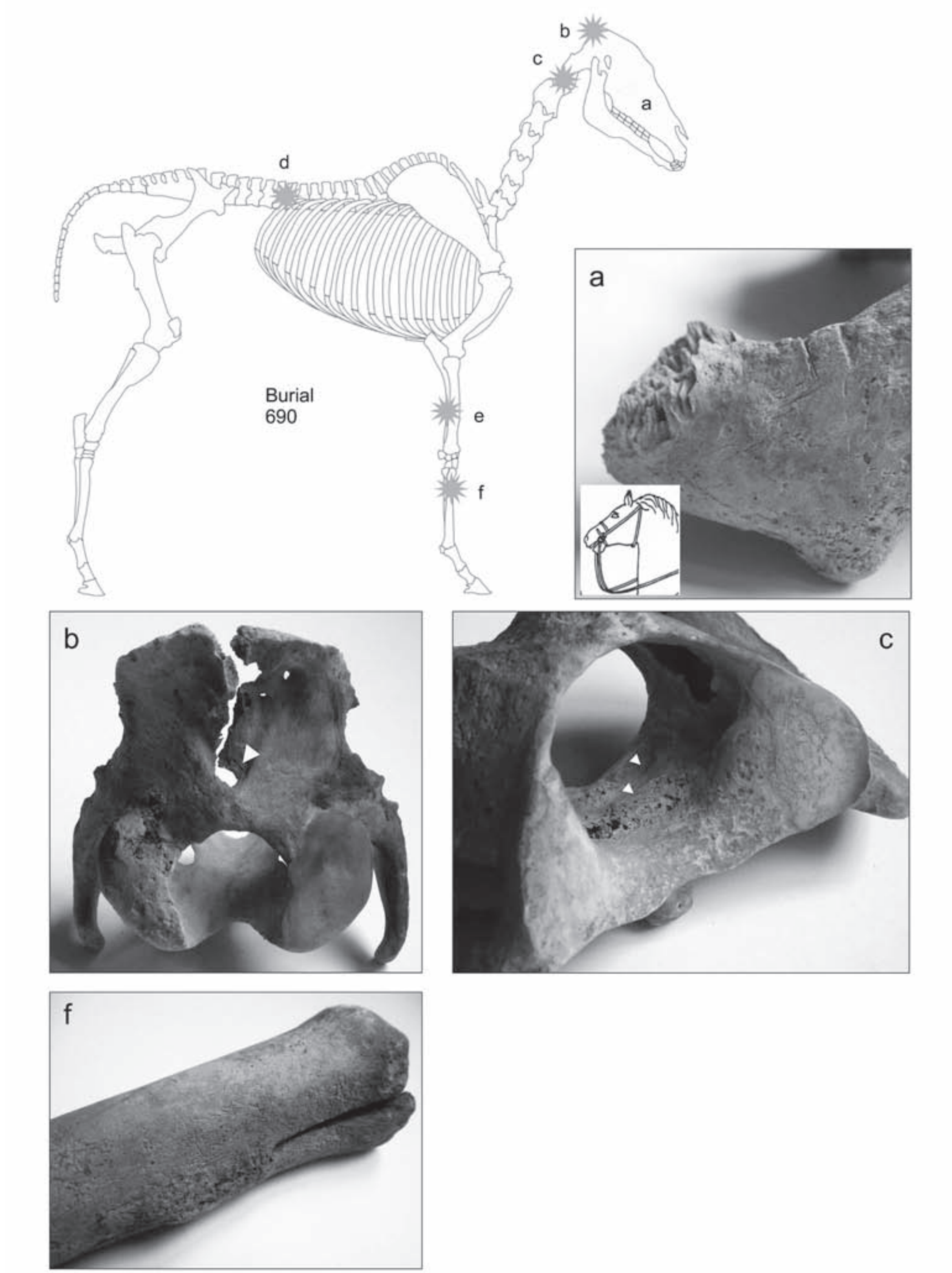

Figure 8.3. Vienna Csokorgasse. Horse from burial 690, probably a male/gelding, ca. *8–9 years old. a) cut marks on the left* arcus zygomaticus*; b) skull, occipital view (GB of the occiptal condyles [34]=79.2 mm); c) atlas (BFcr=82.8 mm); d) 18th vertebra thoracalis (not pictured); e) left radius (not pictured); f) right metacarpus (GL=227.3 mm). Measurements after von den Driesch 1976.*

8.3.3 Burial 692

8.3.3.1 Completeness, sex, age and withers height of the horse

Apart from a few very small bones, the horse skeleton is complete. Even though it was heavily damaged in parts, it was possible to reconstruct almost all regions of the skeleton. It is the best-preserved horse in this cemetery. The maxilla as well as the mandibula carry canines. This, as well as the rounded *ramus acetabularis* of the pubic bone with its marked *tuberculum dorsale*, and the generally narrow and slender pelvis suggest that the animal was a stallion. The horse died at the relatively young age of about 4–4.5 years. All epiphyseal gaps that close late are fused. However, the epiphyseal gap of the femora is still visible. The pelvic apophyses that close at the age of 4.5–5 years are still unfused. The same applies for almost all caudal vertebra epiphyses. Their cranial counterparts, however, are fused. These observations point to an age of four to five years. The dental development of this horse offers more detailed evidence: the third molars are visible but not yet completely erupted (this is to be expected at about three to five years), the canines, however, are erupted completely (happening at four years), and the third milk incisors in both the maxilla and mandibulae were not yet replaced (happening approximately at 4.5 years). Hence, an age of death of about 4–4.5 years seems plausible. The calculated withers height is 138 cm (±8 cm). This horse and the one from burial 690 are the smallest individuals in this assemblage.

8.3.3.2 Special features

This horse is the only one that had first premolar teeth, both superior and inferior.

8.3.3.3 Pathologies

The young horse seems to have been healthy. Its skeleton does not display any pathological alterations.

8.3.4 Burial 693

8.3.4.1 Completeness, sex, age and withers height of the horse

This horse skeleton is somewhat less complete than the others. However, with the exception of some vertebrae and splint bones only small compact bones are missing, as was observed in the case of most other horses. Again, the torso and skull of the animal are heavily fragmented. The shoulder and pelvic regions are primarily damaged on the right side. Most skeletal elements could be reconstructed. The canines in the mandibula and maxilla, as well as the rounded *ramus acetabularis* of the pubic bone with its marked *tuberculum dorsale* and the generally slender and narrow pelvis point clearly to this horse having been a stallion. All epiphyses are fused, with some vertebral gaps still being visible. The fusion lines of the apophyses in the ilium and ischium are also visible. The incisor surfaces are intensively worn down, especially those in the mandibula. These observations point to an age of death at eight to nine years. The estimated withers height is 144 cm (±8 cm). This is the tallest horse in the assemblage.

8.3.4.2 Special features

As in the horse skeleton in burial 650 a sulcus, albeit a slighter one, can be detected on the *processus nasalis* of the os incisivum on both sides.

The canine tooth in the right mandibula carries a smooth snow-white layer on the lingual side. It makes the impression of having been applied carefully and on purpose (Figure 8.4a). The upper canine tooth of the same side displays remains of a similar layer, but it has almost completely disappeared. An X-ray fluorescence analysis carried out by Sonngard Hartmann at the RGZM Mainz revealed that this layer is made up by calcium carbonate ($CaCO_3$), not naturally part of teeth. The substance, however, might result from post-depositional taphonomic soil processes. Calcium carbonate accretions certainly would not last long in the mouth of a live herbivore and a dental treatment of an otherwise healthy tooth seems generally unlikely.

8.3.4.3 Pathologies

This horse, too, displays some pathological lesions (Figure 8.4). The occlusal surfaces of the teeth are unevenly worn. In the area of the second lower molars of both sides a light depression can be seen (Figure 8.4b), and the respective antagonists of the upper molar lines show matching alterations.

The first thoracic vertebra displays a presumably slight inflammatory lesion on the left of its arc (Figure 8.4c). Light exostoses have formed on both sides of the caudal articular surface of the fourth lumbar vertebra. The same applies for its counterpart, the cranial articular surface of the fifth lumbar vertebra. Furthermore, the fourth lumbar vertebra shows a fracture which presumably occurred shortly before the horse was killed, because it seems to have only partially healed (Figure 8.4d). The caudal articular surface is broken horizontally and dislocated. Perhaps this was caused by a sudden heavy impact on the back of the horse, *e. g.* the rider bumping on it after the horse made a jump. Fractures like these are also known from Avar Period horses from Žitavská Tôň and Holiare in Slovakia (Ambros and Müller 1980, 80). The right 14th rib shows an unnaturally strong curvature. However, as it is the only such deformation detected in the entire rib cage, it is possible that this bone was warped in the soil.

The fusion line between the medial splint bone and the right metacarpus III is inflamed and distended (Figure 8.4f, *desmoiditis ossificans ligamentum interosseum*). The same applies for the diaphysis of the left tibia (Figure 8.4e), possibly as the result of a bone marrow inflammation (*osteomyelitis*). The right phalanx 1 posterior displays ossified tendon insertions.

8.4 The dogs

8.4.1 Burial 650

8.4.1.1 Completeness, sex, age and withers height of the dog

The dog skeleton is almost complete. Only some teeth, the sternum, a rib, both patellae as well as some small elements of the autopodium are missing. With the exception of the shoulder blades and the skull, fragmentation is low and most skeletal elements are complete. Given the even better state of preservation of the other dog skeletons, this is nevertheless the most fragmented individual. The presence of the baculum proves that this dog was male. Epiphyses in the skeleton are completely ossified, all epiphyseal gaps are closed and the two pelvic bones are fused at the pubic symphysis. This means that the animal was older than 1.5–2 years, but certainly not much older because the teeth show little to no abrasion. The calculated withers height for this individual is 65.5 cm.

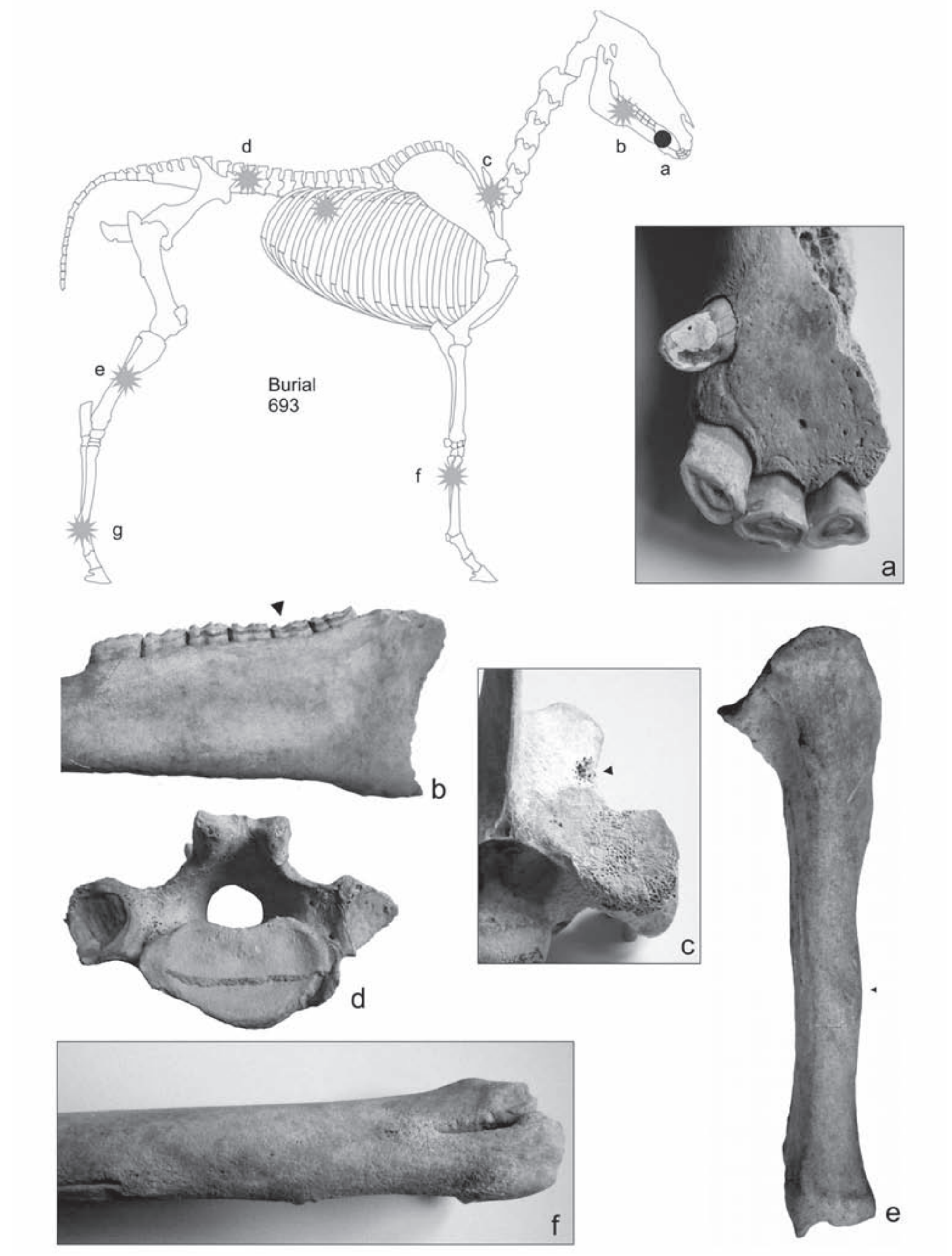

Figure 8.4. Vienna Csokorgasse. Horse from burial 693, stallion, ca. *8–9 years old. a) right caninus inf. with white coating (GB across the curvature of the insisors [16]=64.8 mm); b) right M_2 inf. (L cheektooth row [6]=164.5 mm); c) 1st vertebra thoracalis (H=136.2 mm); d) 4th vertebra lumbaris (BFcr=51.7 mm); e) left tibia (GL=366.8 mm); f) right metacarpus (GL=239.9 mm); g) right phalanx proximalis posterior (not pictured). Measurements after von den Driesch 1976.*

8.4.1.2 Pathologies

Except for two thoracic vertebrae (the fifth and the sixth), whose *processus spinosi* are slightly bent to the left, the young dog seems to have been healthy. The slight curving could be due to an unequal exposure of the trunk muscles.

8.4.2 Burial 690

4.8.2.1 Completeness, sex, age and withers height of the dog

This dog skeleton is the least complete one. Some teeth and vertebrae, the sacrum, five ribs, both patellae, the left fibula and large parts of the autopodium are missing. With the exception of the left shoulder blade and the right femur, fragmentation is low and most skeletal elements are complete. The presence of a baculum offers clear evidence that this dog was male. The skeleton is completely ossified, all epiphyseal gaps are closed and even the two pelvic bones are fused at the pubic symphysis. This means that the animal was older than 1.5–2 years, and certainly not much older because the teeth show little or no abrasion (Figure 8.5a). The calculated withers height for this individual is 63.7 cm.

8.4.2.2 Pathologies

The dog suffered from some calamities (Figure 8.5). During its lifetime, it lost all upper incisors, both upper first premolars, the right second upper molar (Figure 8.5a) and the left first lower premolar.

On the right side of the occipital area, some ossified tendon insertions are visible on the os interparietale and the *crista sagittalis* externa. (Figure 8.5b).

The caudal articular surface of the axis carries very small osteophytes. As is also the case for the dog skeleton from burial 650, some thoracic vertebrae (the sixth to the ninth and the eleventh) show a curved *processus spinosus*, in this case to the right side (Figure 8.5d). Osteophytes developed on the articular surfaces between the 13th thoracic vertebra and the fifth lumbar vertebra. More than that, these vertebrae display massive bone formations on their *processus spinosi* (Figure 8.5e).

Ribs of both sides (left rib 9, right ribs 8, 12 and 13) have bulging nodules in the middle of their *corpora* (Figure 8.5f). These could stem from healed fractures, but they could also be symptoms of a tuberculosis infection (Csippán/Daróczi-Szabó 2008, 75 fig. 10.2). The bony bridge between the left fibula and the respective tibia is supposedly the result of a fibula fracture (Figure 8.5g). Due to inflammatory processes, the left metatarsus II is distended enormously under massive callus formation (Figure 8.5h). A fistula has formed to drain off liquid build-up and a partial fusion with metatarsus III has occurred.

8.4.3 Burial 693

8.4.3.1 Completeness, sex, age and withers height of the dog

Only the right patella and some autopodium bones are missing from this skeleton. Furthermore, the degree of fragmentation is very low. The presence of a baculum is indicative of this dog having been a male. The skeleton is completely ossified, all epiphyseal gaps are closed and the two pelvic bones are fused at the pubic symphysis.

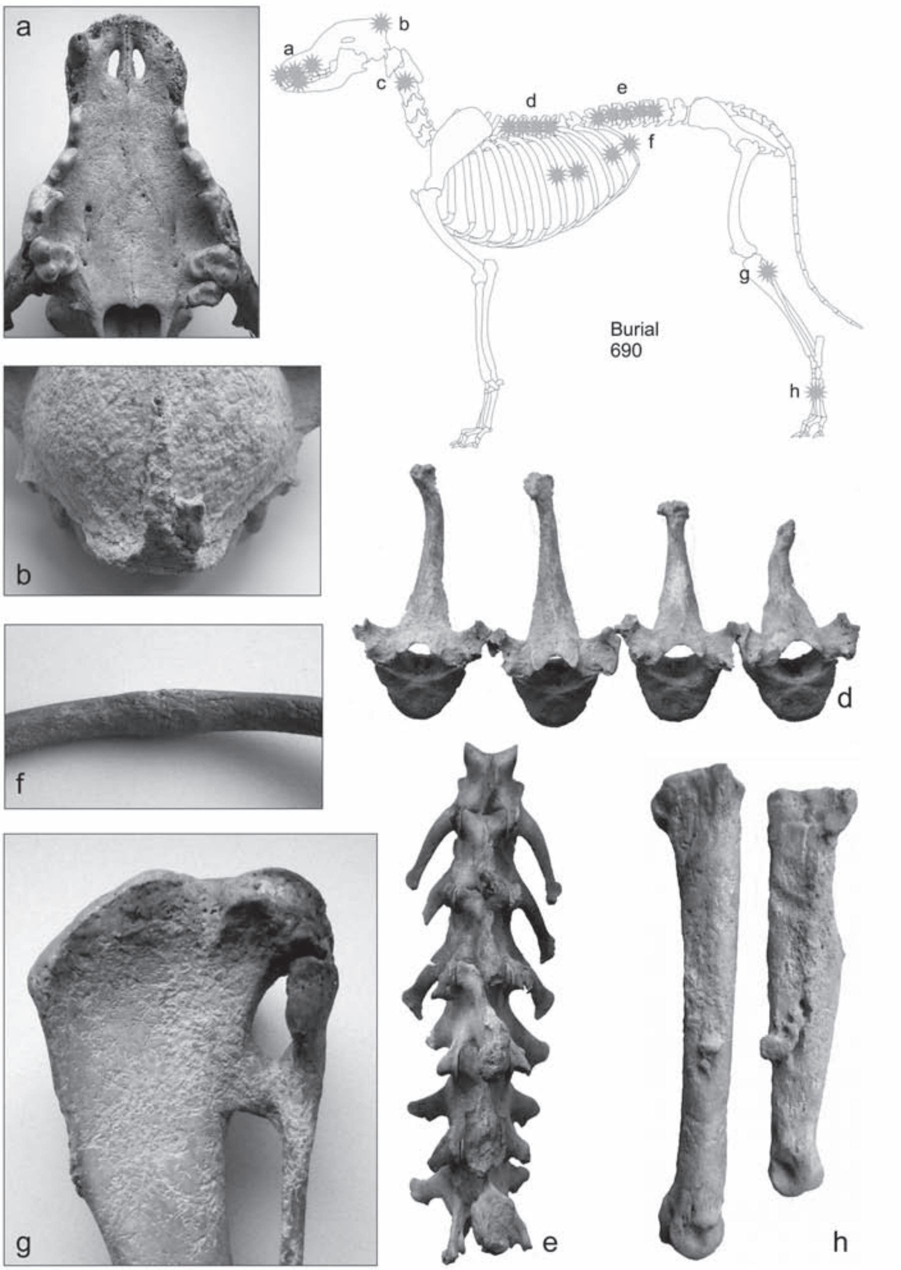

Figure 8.5. Vienna Csokorgasse. Dog from burial 690, male, ca. *1.5–2 years old. a) superior teeth (Greatest palatal breadth [34]=69.8 mm); b) skull,* crista sagittalis externa *(Greatest neurocranium breadth [29]=68.6 mm); c) axis (not pictured); d)* vertebrae thoracales *(medium BFcr=25.3 mm); e) vertebrae lumbares (medium BFcr=25.3 mm); f) right costa; g) left tibia and fibula (GL=216.5 mm); h) left metatarsus II and III (GL MtII=70.6 mm, GL MtIII=83.1 mm). Measurements after von den Driesch 1976.*

This means that the animal was older than 1.5–2 years. The teeth show medium heavy to strong abrasion. This dog was presumably the oldest in this cemetery, and had a calculated withers height of 64 cm.

8.4.3.2 Pathologies

This dog, too, suffered some calamities in his lifetime (Figure 8.6). The left zygomatic bone shows some deformation: the zygomatic arc was subject to trauma at the fusion line between the *processus temporalis* of the os zygomaticum and the *processus zygomaticus* of the os temporale, where a callus has formed (Figure 8.6a). Apart from that, a partially healed impression fracture can be detected on the left maxilla and the nasalia: the left nasal bone shows a large indentation (Figure 6b). The crown of the right first inferior premolar seems to have been broken off in the dog's lifetime, with the result that the remaining tooth turned brown. The neighbouring second premolar had been lost *intra vitam* and its alveolus absorbed completely (Figure 8.6c).

The *processus spinosi* of the thoracic and lumbar spine sections (fifth thoracic to seventh lumbar vertebrae) are curved, too, in this case to the left. And this dog also had some ribs that grew nodules (left rib 4, right ribs 7 and 11). The nodules appear in part more in the ventral section of the ribs, and partially also laterally (Figure 8.6e). Both fibulae show pathologies: the left one fused in its medium to distal section along with the tibia (Figure 8.6f), and the right one shows a well healed fracture in the middle of the diapyhsis (Figure 8.6g).

8.5 Discussion

The zooarchaeological analysis of the horse and dog skeletons under discussion here did not provide evidence of how the Avars killed these animals. With the exception of the horse in burial 690 that seems to have suffered a blow to the occipital region of the head (Figure 8.3b), no traces were found that could hint to the method of slaughter. It is therefore unclear whether the animals were killed and then placed carefully in the grave or whether they were killed in the grave-pit itself.

8.5.1 The horses

The age spectrum of the horses ranges between four and nine years, and their bridle and saddle remains hint to them being active riding horses. Horses of this age tend to be already broken in and still usable if treated well. The exostoses in the rear spinal area of the three older horses with an early stage of *spondylosis ankylosans* possibly resulted from riding (Ambros and Müller 1980, 80–81; Bartosiewicz and Bartosiewicz 2002). These animals also displayed different degrees of *desmoiditis ossificans ligamentum interosseum* between their metapodial bones which could also be related to physical strain on the legs, be it due to riding or labour. It is not unusual that this condition first occurs in the medial splint bone of the fore limb before it affects the hind legs (Daugnora and Thomas 2005), although even in ten non-working Przewalski horses the fusion between the medially located second and third metacarpus was most frequently recorded (Bendrey 2007, 209–210). The irregular dental abrasion displayed by the two horses from burials 650 and 693 may result from the friction of the snaffle bit and

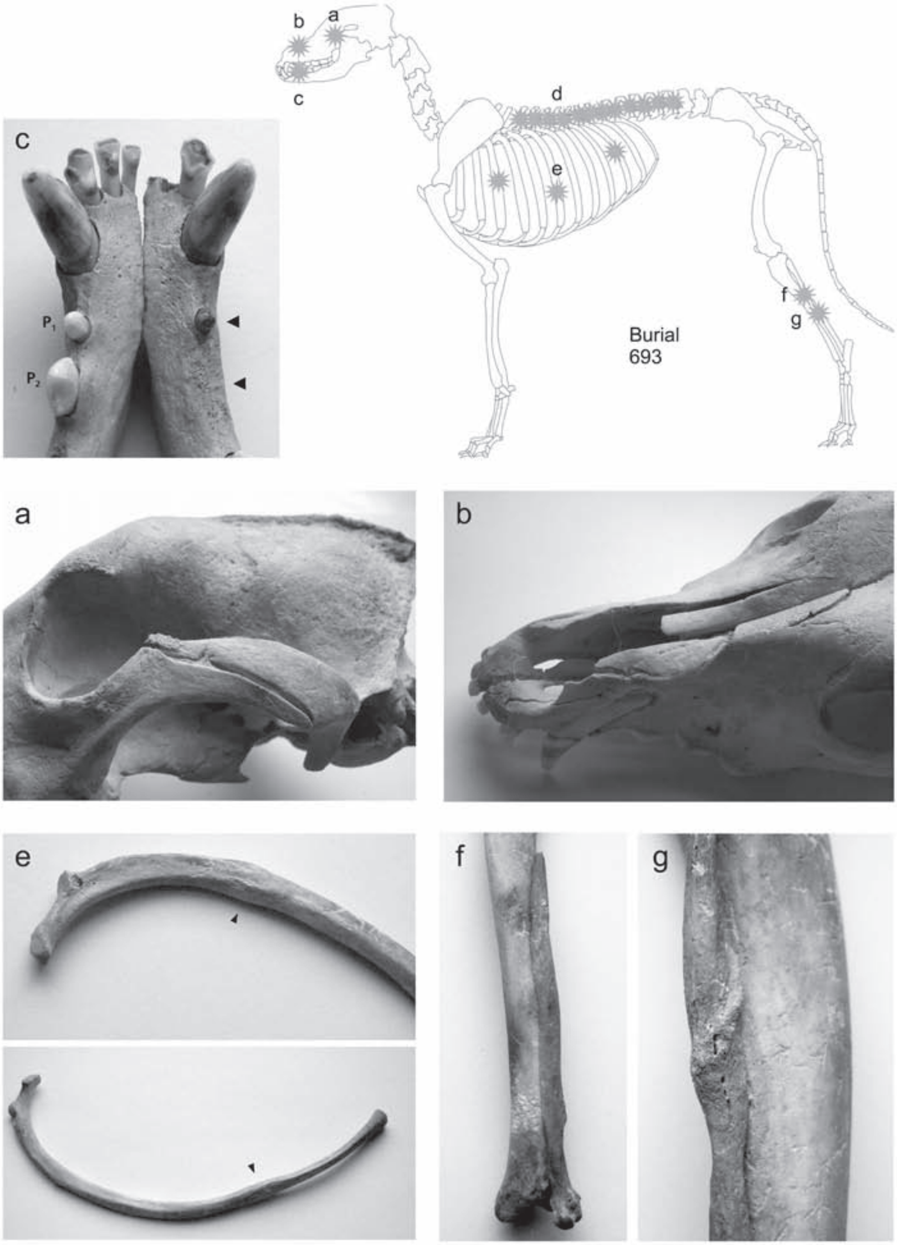

Figure 8.6. Vienna Csokorgasse. Dog from burial 693, male, more than two years old. a) left arcus zygomaticus *(Least palatal breadth [35]=34.1 mm); b) left os nasale (Snout length [12]=92.8 mm); c) left and right incisors, canines and premolars, sup. (Total length left mandible [1]=155.9 mm); d) vertebrae thoracicae and lumbales (not pictured); e) costae; f) left fibula and tibia (GL=221.6 mm); g) right fibula and tibia (GL=219.6 mm). Measurements after von den Driesch 1976.*

hence these are also evidence of riding (Figure 8.4b). These symptoms observed on teeth, vertebrae and metacarpals need not necessarily have impaired the usability of the horses. The same applies for the incipient ossification of tendons, as on the atlas of the horse from burial 650, on the radius and *crista nuchae* on the neurocranium in the horse from burial 690 and the proximal phalanx of the horse from burial 693.

The arthritic alterations, however, especially when reaching a severe degree marked by a complete degradation of the cartilage and the chafing of bone on bone, must have been painful and certainly caused the animal to take up a relieving posture. This could be the case for the atlas of the horses recovered from burials 650 and 690 (Figures 8.2c, 8.3c), as well as the metatarsus III and two phalanges of the former. Inflammations observed on the scapula and metacarpus of the horse in burial 650 (Figure 8.2j) and on the first thoracic vertebra and left tibia of the horse from burial 693 (Figure 8.4c, e), certainly caused pain and discomfort. The same applies for the alveolar inflammation the horse found in burial 650 suffered from (Figure 8.2b). It certainly was painful for it to feed. Perhaps this visible problem could have been eased by the owner.

Nevertheless, all animals were still usable when they died. I agree with C. Ambros and H.-H. Müller regarding their opinion that elderly, useless old nags were not selected for burial purposes but rather active, usable riding horses were deliberately chosen; furthermore, these could be presumed to belong to the respective deceased (Ambros and Müller 1980, 82). After all, one of the four burials contained a healthy young horse that would have been perfectly well usable – at least physically (it must be borne in mind that the temper of the animals also played a vital role in their usability as mounts).

Concerning withers heights, the horses from these Avar burials conform well with horses from other Avar cemeteries. It also seems that their selection for this ritual purpose with regard to age, sex and general usability followed the same or very similar criteria as elsewhere in the Avar Empire.

8.5.2 The dogs

The dogs buried with horse and rider reached impressive withers heights of 64 to 66 cm. Comparable shoulder heights are today typical for trained sheepdogs and guard dogs such as the German shepherd or the *Kuvasz*, or for hunting breeds such as sighthounds. We can assume that Avar dogs had comparable purposes. Judging from the pathologies of at least two of them, they had no calm life at the fireside. Both animals from burials 690 and 693 show fibula fractures (Figures 8.5g, 8.6g), furthermore the latter displays traumatic injuries inflicted onto the skull (Figure 8.6a, b). The impression fracture on this animal's snout presumably occurred in action – and it is quite possible that it stems, for example, from an unruly ruminant the dog tried to discipline. Both these dogs lost teeth during their lifetimes, a condition especially marked in the individual brought to light from burial 690 (Figure 8.5a), which also suffered from a heavy osteomyelitis on its left metatarsal region (Figure 8.5h) which certainly rendered it lame.

The two older dogs from burials 690 and 693 have two more pathological lesions in common: both show bulging nodules on their ribs (Figures 8.5f, 8.6e) which could be due to tuberculosis. This infection is caused by a mycobacterium and affects the lungs. It is assumed that it can leave such nodules on the rib-cage. Furthermore, both animals,

and to a lesser degree also the younger dog discovered in burial 650, display curved *processus spinosi* on their spine (Figure 8.5d). Fasciuli of the *musculus multifidus spinae*, stabilizing the joints within the spine, are attached to these processes, which flexibly tie the elements of the spine together. A highly unequal strain between the body sides may have caused such curvatures of these *processus spinosi*. However, I am not aware of any studies of this phenomenon.

8.6 Conclusions

When the Avars entered the Carpathian basin in the mid-6th century, they were mounted warriors raiding cities, towns and villages, and they terrified the autochthonous people with their ability to fight from horseback. After the failed siege of Constantinople in 626, however, they turned to a more peaceful lifestyle marked by rural activities, mainly assumed to be agricultural pursuits. Hence it is likely that the horses which accompanied their masters (presumably) into their graves during the 7th and the 8th centuries were already spared from being exposed to the terrors of Early Mediaeval warfare. The functional unit of horse, rider and dog points to use in mundane activities such as herding sheep and cattle. The adornment of the animals in burial 650 with bells and the skull injury one of the dogs suffered could have something to do with these occupations.

Acknowledgements

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9. Horseback Riding, Asymmetry, and Changes to the Equine Skull: Evidence for Mounted Riding in Mongolia's Late Bronze Age

William Taylor and Tumurbaatar Tuvshinjargal

A primary obstacle facing the study of early horse transport is the challenge of identifying ridden horses in the archaeological record. While changes to the equine skull and dentition may help identify animals that were bridled and heavily exerted, these features are typically insufficient to distinguish riding mounts from animals used to pull vehicles. This paper suggests that asymmetric deformations to the equine skull, found on domestic horses, may be useful for identifying ancient ridden specimens in archaeological contexts. Contemporary nomadic herders in Mongolia use a bridle that pressures the skull in several places, typically riding with the reins held in the left hand. Preliminary analysis of modern and historical Mongolian horse skulls contexts suggests that this riding style could cause deformation and thinning of the left nasal bone and remodelling of the right margins of the premaxilla. A small sample of horses dating to the Late Bronze Age also displayed these patterns, a result that may help understand the ambiguous chronology of equine transport among early herding societies in the region. This research suggests that cranial asymmetry may help to distinguish riding mounts in the archaeological record, and complements a growing body of evidence that horseback riding was established in Mongolia by the Late Bronze Age.

9.1 Introduction

Although horses were domesticated as early as the 4th millennium BC (Olsen 2006; Outram *et al*. 2009), the timing of the emergence of mounted horseback riding – particularly in eastern Eurasia – is less well understood. Horses were used to pull chariots across much of the continental interior during the 2nd millennium BC (Drews 2004, 50–51; Kelekna 2009, 63), and some scholars suggest that horses must also have been ridden by Central Asian nomads at this time (Anthony *et al*. 1991; Anthony and Brown 2003). However, the first unequivocal historical records of competent mounted riding appear to date to the early first millennium BC (Argent 2011, 31; Drews 2004, 66).

Among the earliest domestic horses known from eastern Eurasia come from an archaeological culture known as the Deer Stone–Khirigsuur (DSK) complex (Fitzhugh 2009, 189; Honeychurch 2015, 121). Named for the carved stone megaliths (deer stones) and burials (*khirigsuur*s) that were constructed across much of Mongolia and eastern Central Asia during the Late Bronze Age (*c*. 1200–700 BC), this culture has been linked with a mobile herding lifestyle and the emergence of social inequality in the region

(Houle 2009, 372). Many deer stone and *khirigsuur* ritual sites are characterised by large numbers of small stone mounds, containing the heads and hooves of sacrificed horses.

Despite their ubiquity, it is unclear how these ritually interred horses were used by DSK herders. Deformation to the nasal bones of both old and young horses recovered from such contexts suggests that many were bridled or haltered (Taylor *et al*. 2016), and changes to the premaxilla linked to heavy exertion suggest they were used for transport of some kind (Taylor *et al*. 2015). A few deer stones depict chariot images, and many researchers reasonably assume that DSK people used horses to pull chariots (*e.g*. Erdene-Ochir and Khyadkov 2016, 23–30). However, it is probable that, prior to its widespread emergence in the 1st millennium BC, horseback riding was practiced by nomadic herders living in the continental interior (Mair 2003, 181). The rapid spread of horse ritual features across Mongolia *c*. 1200 BC hints at a major, horse-related social transformation that could correspond to the innovation or adoption of horseback riding (Taylor *et al*. 2017). Other than the faunal remains of sacrificed horses, however, no grave goods and few artefacts have been recovered from DSK sites with which to evaluate directly how these horses were used by Late Bronze Age people.

9.1.1 Identifying Mongolian riding: an ethnoarchaeological approach

One potential avenue for distinguishing horses used as draught animals from those used for mounted horseback riding may be found in the riding traditions of contemporary horsemen in eastern Central Asia. Because one hand must be used often for other purposes Mongolian herders typically ride with the reins held in the left hand (Figure 9.1). This scenario is mirrored in other riding traditions, such as American cavalry, or contemporary competition riding in the western United States. For the right-handed rider, left-handed rein control enables the more dexterous hand to hold other equipment such as whip (Mongolian: *tashuur*), lasso, or lasso pole (Figure 9.2). Traditional Mongolian bridles use a noseband that is directly attached to the reins. When the reins are pulled, this noseband directly pressures the bridge of the nose, and provides a braking function. The bit most commonly used is a unique kind of jointed snaffle, with elongated, curved canons that protrude far outside of the mouth, and focus pressure on the mouth corners. These bridles are used in conjunction with many different styles of cheekpiece or *zuuzai*, including small rings, large rings, and rings with vertical bar extensions. When riding at a gallop, Mongolian riders stand in the stirrups, using the reins for both control and stability (Figure 9.2).

This combination of tack and riding style might produce osteological deformations to the equine nasal bones. Deformation caused by bridling or chronic halter use has been previously recognised on both horse specimens from archaeological sites (*e.g*. Bartosiewicz 2014, 132; Takács 1985), and modern Central Asian horses (Taylor *et al*. 2016). Many factors likely influence the formation of this feature, including the age of the animal when bridled, type and fit of the bridle and tack, and the frequency and kind of riding or transport in which the animal is used (Taylor *et al*. 2016). In particular, the constant presence of an overtight halter may be one especially important factor influencing deformation (Takács 1985, 312). However, pressures caused by a tight halter should be even and symmetric. In contrast, because rein tension nearly always originates from the left, left-handed reining should place a more consistent load of

Figure 9.1. A group of Mongolian riders watch a horse race in Khuvsgul province, northern Mongolia. Image shows the ubiquity of the left-handed riding posture.

Figure 9.2. Mongolian herder riding left-handed, leaning to one side and stabilising himself with the reins, with visible pressure the left nasal area. Herder using lasso pole visible in background. Photo by Orsoo Bayarsaikhan photography.

rein tension on the left side of the nose during riding. Consequently, this fact should be reflected in asymmetric remodelling of the nasal bones among modern Mongolian horse skulls.

Bridle cheekpieces may also produce changes to the skulls of horses ridden by contemporary Mongolian nomads. Equine crania observed in museum collections often display a groove to the lateral aspect of the premaxilla (Figure 9.3), which appears linked to use in transport (Taylor *et al*. 2015). This groove is associated with a nasal branch of the infraorbital nerve, which runs close the margin of the premaxilla. Bone remodelling of the premaxilla at this location probably occurs to protect the nerve and blood vessels from compression (Perez and Martin 2001, 358). The source of this compression is unclear. While the feature was initially linked to the development of rigid nasal muscles in heavily trained animals, a recent comparative study raised the possibility that grooving is exacerbated by chronic pressure or irritation caused by bridle equipment (Taylor *et al*. 2016).

According to our ethnographic informants, the contemporary Mongolian *zuuzai* functions not only as a turning aid, but also to prevent the bit from passing entirely through the mouth when the reins are pulled. Veterinary experimental work has demonstrated that on a snaffle bridle, pulling a single rein moves the opposing cheekpiece medially, where it contacts the side of the mouth and face (Clayton and Lee 1984). With the reins held in the left hand, the cheekpiece is thus more likely to contact the right facial exterior during riding activities, unless an appropriate countering force is consistently applied each time the reins are pulled. If premaxillary remodelling can be reliably linked to interaction between the cheekpiece and the infraorbital nerve, contemporary and ancient horses ridden with a Mongolian bridle or similar configuration should display more severe remodelling on the right premaxilla.

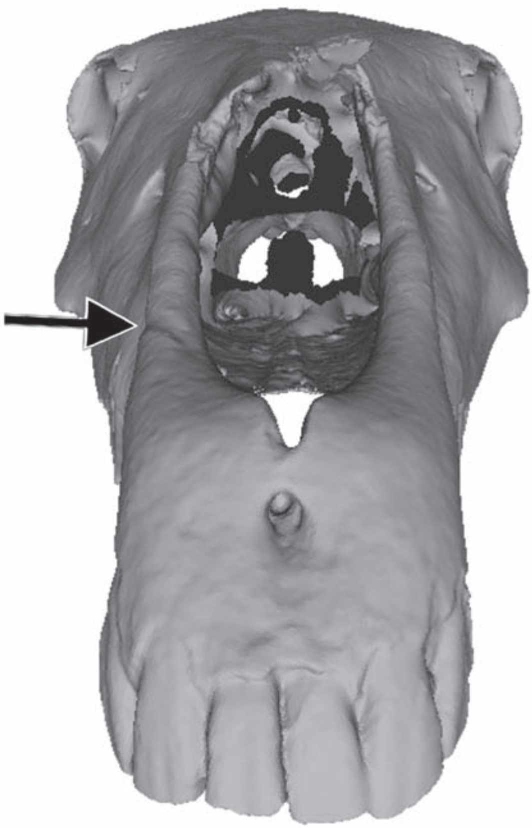

Figure 9.3. Asymmetric lateral remodelling to the premaxilla caused by remodelling of the bone in the area of the infraorbital nerve, shown on an archaeological specimen from Mongolia.

Lastly, the use of a metal bit is linked with oral damage which may help identify left-handed horse riding. One of the most well-known anthropogenic features connected with horse transport is "bit wear", or bevelling of the second lower premolar caused by metal bit use (Anthony *et al*. 1991; Anthony and Brown 2003; Anthony and Brown

2006). Because natural problems with dental occlusion can also alter the second premolar, the validity of bit wear as evidence for horseback riding has been questioned over concerns about equifinality (Bendrey 2007; Levine 1999; Olsen 2006). Some scholars have even doubted the very premise that a metal bit can interact with the premolars long enough to cause recognisable alterations (*e.g*. Sasada 2013). Nonetheless, “chewing” of the bit while bridled has been observed under clinical examination (Clayton and Lee 1984; Manfredi *et al*. 2010). Some equine dentists link the chronic form of this behaviour with specific changes to the teeth – displacement, remodelling of the alveoli, formation of a smooth, dome-shape to the upper premolars, and a flat, smooth ramp on the lower premolars (*e.g*. Johnson and Porter 2006). Horses that chew the bit sometimes exhibit a preference for one side of the mouth, but they more usually favour both sides equally (Johnson and Porter 2006). Consequently, any occlusal damage to horse teeth caused by this behaviour might not result in recognisable asymmetry.

However, some kinds of horseback riding may also cause incidental contact with the horse’s premolars that could produce asymmetric dental damage. Direct contact with the bit can damage the oral margin of the lower second premolar in a characteristic fashion (Bendrey 2007). In contrast to occlusal damage, this oral wear occurs rarely among unbitted animals, making it a more reliable index of bit use (Bendrey 2007, 1041, 1049). On a snaffle bridle, pulling a single rein produces caudal displacement of the bit on the near side, bringing it closer to the premolar margins (Clayton and Lee 1984). The Mongolian bit protrudes significantly beyond the sides of the horse’s mouth – giving it even more freedom of movement – and during ethnographic observations we often observed the bit pulled back to a point of contact with the lower second premolars. To the extent that left-handed reining also produces more pulling from the left, Mongolian horses might exhibit an increased frequency of dental changes to the left side of the mouth.

These predictions should also hold for ridden horses from archaeological contexts. Finds of ancient of horse tack indicate that ancient Mongolian bridles also used a direct noseband attachment, with cheekpieces as turning aids (Taylor *et al*. 2016). Images and artefacts also suggest that the left-handed riding style may have great antiquity in eastern Central Asia. Contemporary and ancient depictions of mounted nomadic warriors from the middle ages nearly always show riders holding the reins in the left hand (*e.g*. Figure 9.4; also see Yatsenko 2015). Well-preserved bridles from the Pazyryk culture of the first millennium BC sometimes had a “lead rein” on the animal’s left side (Argent 2011, 146), suggesting that riders handled and mounted horses from the left. Prior to the invention of saddles and stirrups, Late Bronze and early Iron Age riders probably used the reins to stabilise and balance themselves to an even greater degree.

In summary, if asymmetric cranial changes characterise contemporary Mongolian horses, similar patterns should also be observed on horses from the 1st millennium BC and after. But would such asymmetry help to distinguish riding from chariot driving?

Ancient chariot horses might also have experienced asymmetric rein pressures. Carvings on Mongolian rock panels (Honeychurch 2015, 121) and deer stones themselves (Nyambat and Odbaatar 2010, 63–64) indicate that Late Bronze Age Mongolian people likely used chariots. These light, two-horse carts would have been controlled by a single

Figure 9.4. Statue depicting a warrior from the Great Mongol Empire, 13th–14th centuries CE, outside the Parliament building in the capital city of Ulaanbaatar.

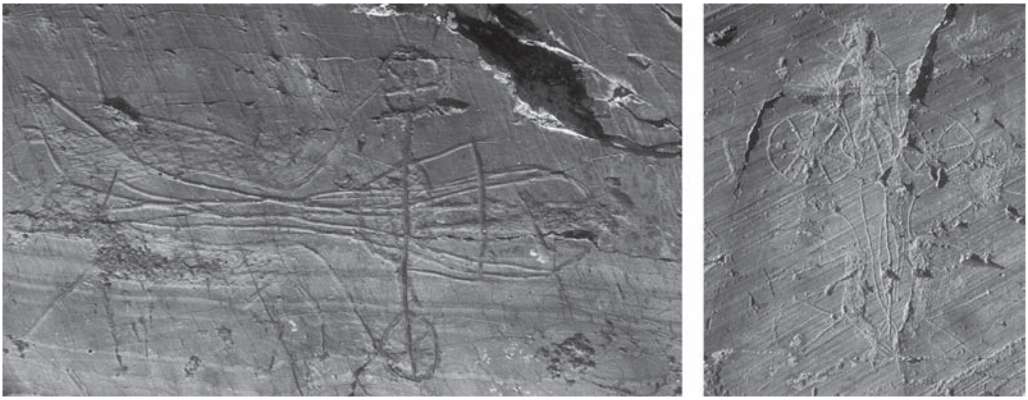

Figure 9.5. Petroglyphs from Tsagaan Gol in western Mongolia, showing driver holding two sets of reins, and reins running through a terret affixed to the pole (right). Photographs: Gary Tepfer. Copyright: Mongolian Altai Inventory Collection, University of Oregon. Reprinted here with permission.

driver, with separate sets of reins for each animal on the left and right (Figure 9.5). If a horse was kept in the same team position over the course of its lifetime, it might conceivably experience unequal chronic tension from a single direction, despite never having been used for mounted riding. In the aggregate, though, this scenario should produce roughly equal numbers of horses used on either the left or the right, rather than the consistent asymmetry anticipated from left-handed horseback riding.

A second, more problematic, possibility is that the behaviour of the chariot driver could produce regular pressure from the left direction. Based carvings with visible reins, early Mongolian chariots – at least in some cases – appear to have been controlled by reins running freely from the bridle to the driver. If a charioteer favoured left-sided turns for tactical reasons, or due to natural instincts, rein activity could conceivably produce chronic asymmetric pressures favouring the animal's left side. Future study will be necessary to explore this possibility in depth. However, petroglyphs typically depict reins held by the charioteer with both hands, or tied to the centre of the driving box, and sometimes show reins through terrets or guides attached to the central draught pole (Figure 9.5). Subsequently, it seems that pressure and attendant asymmetry should be less frequent and less pronounced among chariot animals. In this case, the presence of marked cranial asymmetry in horses recovered from archaeological sites would strongly support the hypothesis that said horses were ridden, rather than driven.

9.2 Materials and methods

To test the hypothesis that deformation asymmetry is related to left-handed riding, we conducted osteological analysis of modern and archaeological horse skulls from Mongolia, comparing these specimens to previously analysed control samples of wild and domestic horses from museum collections (Table 9.1). Because Mongolian horses begin training for riding between one and two years of age (Enktuvshin and Tumurjav

Table 9.1. Samples used in this study, along with number of specimens analysed for cranial deformations and oral bitting damage.

Specimens	*No. examined*	*With cranial data*	*With dentition data*
Contemporary Mongolian horses	15	15	6
Iron and Middle Age Mongolian horses	8	6	8
Contemporary American domestic horses	12	12	–
Contemporary American feral horses	7	7	–
Contemporary Przewalski horses	6	6	–
Bronze Age Mongolian horses	48	13	48

2011, 173–174), and a horse's permanent premolars emerge at around 2.5 years, we excluded all animals younger than three years (estimated by dental eruption following Evans *et al*. (2006)) from our analysis.

9.2.1 Contemporary Mongolian horses

We collected a sample of 15 adult horse skulls via surface collection in the Mongolian countryside in several regions of central and western Mongolia, including Tuv, Uvurkhangai, and Gobi-Altai provinces. Similar bridle styles are used by herders across the region, so these crania should effectively characterise deformation patterns among animals ridden with a Mongolian bridle. Age and sex estimates of these and all subsequent specimens are provided in Appendix I (Available at: http://doi.org/10.6067/XCV8ZW1PK4).

9.2.2 Iron and Middle Age Mongolian horses

We analysed the cranial remains of 8 adult horses from archaeological sites, buried with riding tack, and dating to the era of mounted horseback riding cultures – the Iron Age and early Middle Ages. These included one Pazyryk (*c*. 600–200 BC) horse from western Mongolia, two Xiongnu (*c*. 200 BC–AD 100) specimens from north-central Mongolia, one Xianbei horse from Orkhon province in central Mongolia (*c*. AD 150–250), three horses from the time of the Turkic Khaganate in western and central Mongolia (*c*. 6th–8th centuries AD), and one male horse from the Khitan Period (10th century AD). Of these, two consisted of only a lower mandible, and lacked relevant portions of the cranium (nasal bones or premaxilla).

9.2.3 Contemporary American and Przewalski horses

We also studied a sample of previously collected, high resolution 3D scans of 11 domestic American racehorses, farm horses, and military horses from American museum collections (Appendix I). Five of these sample specimens (the war horse

Kidron ridden by John Pershing, the racehorses *Lexington, Hanover, Sysonby, Haleb*, and the competition horse *Indraff*) had photographic documentation of tack. None of the bridles we identified had a link between the noseband or halter and the reins, making them unlikely to produce pronounced deformation of the nasal bones or left-biased asymmetry. Moreover, although some of these animals were controlled with rigid cheekpieces, the primary effect of these documented bits (such as a curb or snaffle) is on the palate or bars of the mouth. Consequently, these animals should exhibit a greater degree of bilateral symmetry in cranial deformations linked to human activity.

We compared these ridden animals to a group of 13 adult equids which had never been bridled or ridden, including six feral domestic horse skulls – museum specimens recovered from areas occupied by feral herds on Assateague Island in Virginia/ Maryland, and north-western New Mexico – along with seven Przewalski horse skulls from zoos and wild reserves (Appendix I).

9.2.4 Bronze Age Mongolian horses

Finally, we compared our compiled data to a large sample of 46 adult specimens recovered from individual horse burial features at deer stone and *khirigsuur* sites across Mongolia. Due to fragmentation and taphonomic issues, 12 of these horses had sufficient preservation to assess premaxillary morphology, and only two skulls had sufficient preservation to assess the presence of nasal remodelling (analysis described in Taylor *et al.* 2016, 563).

9.2.5 Data collection protocols

9.2.5.1 Nasal and premaxillary remodelling

Using a NextEngine3D desktop laser scanner, we created a digital 3D model of each specimen at a resolution of 2000 DPI. For contemporary American domestic and feral animals, as well as Przewalski horses, we used previously collected 3D data. We used these models to measure the maximum depth of premaxillary and nasal remodelling on both the left and the right aspect of the skull using open-source measurement software (GOM Inspect).

9.2.5.2 Dental pathologies linked to bitting

We measured the bevelling to the occlusal surface of the lower premolars on all specimens except the contemporary American and Przewalski horses, for which only previously collected 3D models of the upper crania were available. We followed the protocol outlined by Anthony and Brown (2003), using Mitutoyo digital callipers to record bevel depths. For specimens exhibiting a measurable premolar bevel, we refit the skull with the lower jaw to identify cases caused by malocclusion. We also recorded the presence or absence of the "Greaves effect", wherein the enamel and cementum wear naturally at different rates due to differential composition and hardness. When the Greaves effect is absent – meaning that the enamel and cementum have worn evenly and flat, and the jaw shows few signs of malocclusion when refit – an occlusal premolar bevel may be indicative of bit wear (Olsen 2006, 100–101). For each horse, we

recorded instances of parallel-sided enamel exposure to the oral margin of the second premolar (P_2) tooth (Bendrey 2007), along with cases of non-diagnostic enamel exposure, *in vivo* tooth fractures, alveolar remodelling, and other abnormalities for both upper and lower premolars.

9.3 Results

9.3.1 Nasal remodelling

Three of the 13 contemporary Mongolian horses in our study sample displayed a marked concavity to the bridge of the nose, and two of these also displayed asymmetric bone thinning to the left nasal bone (Figure 9.6). One adult male horse from Morin Mort, Bayankhongor province exhibited especially dramatic nasal deformation of 3.7 mm in depth, which has been described elsewhere (Taylor *et al*. 2016, 558). This feature is nearly perfectly symmetric, and may have been caused by a halter. As all modern Mongolian specimens were collected from surface collection, they likely experienced variable local taphonomic conditions that cannot easily be controlled for.

Among the Mongolian horses dating to the Iron Age and onwards, very few (n=4) had sufficient preservation to assess nasal morphology. One of these specimens, a partially mummified young male horse from the site of Ulaan-Uneet, dating to the time of the 10th century AD, exhibited marked and asymmetric remodelling – a deep recess of over 4 mm in depth on the left side of the nasal bones (Figure 9.7, left).

Within our control group of 11 contemporary American domestic horses, none exhibited clear evidence of deformation to the bridge of the nose. Only one specimen, *Kidron*, showed a possible instance of deformation: a slight, symmetric interruption in the nasal profile. This feature could relate to the chronic use of a U.S. Cavalry bridle, which incorporates a detached noseband only indirectly connected to the reins (and thus unlikely to pressure the skull during riding). Nasal deformation features were entirely absent from contemporary Przewalski horses and feral domestic horses.

Nasal deformation on one of two complete Bronze Age horses, from the site of Khushuutiin Gol in northern Mongolia, was markedly asymmetric – with a deep depression of more than 4 mm in depth on the left nasal bone, and only a shallow groove of around 1 mm on the right. Symmetric nasal remodelling

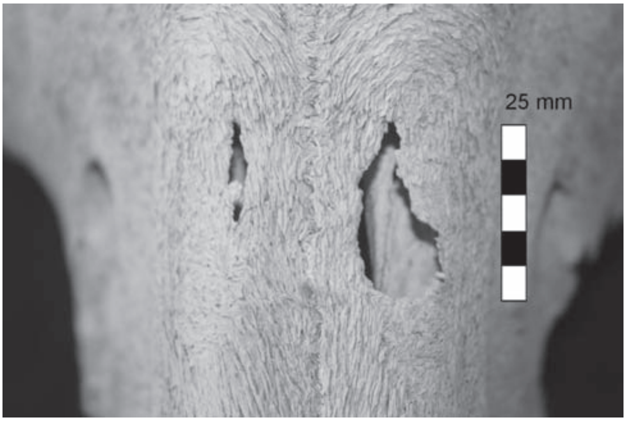

Figure 9.6. The nasal bones of a horse from Uvurkhangai province in central Mongolia, showing pronounced taphonomic weathering to the animal's left side in the area of nasal deformation.

was also visible on two juvenile horses (1–3 years old) which exhibited moderate deformation.

9.3.2 Premaxillary remodelling

Seven of the 13 contemporary Mongolian horses with measurable premaxillae displayed deeper grooves on the right side, in some cases showing a discrepancy of more than 1 mm between the left and right. In contrast, only three observed specimens were symmetrical (*i.e.* no premaxilla grooving), and three exhibited a slightly deeper groove on the left (Figure 9.8). Fewer specimens were available to characterise archaeological riding mounts dating to the Iron Age and onwards (seven adult horses), premaxilla grooving also appears asymmetric in this sample (Figure 9.8, second from right). Interestingly, two animals dating to the early Turkic period (6th–8th centuries AD) had an appreciably larger groove on the *left* premaxilla (Figure 9.8b). Still, the mean depth was larger for right premaxillary grooves – one specimen from the Xiongnu culture (*c.* 200 BC–AD 100) had a negative groove differential of nearly 1 mm. Because of the small sample and effect size, these apparent patterns cannot be statistically validated.

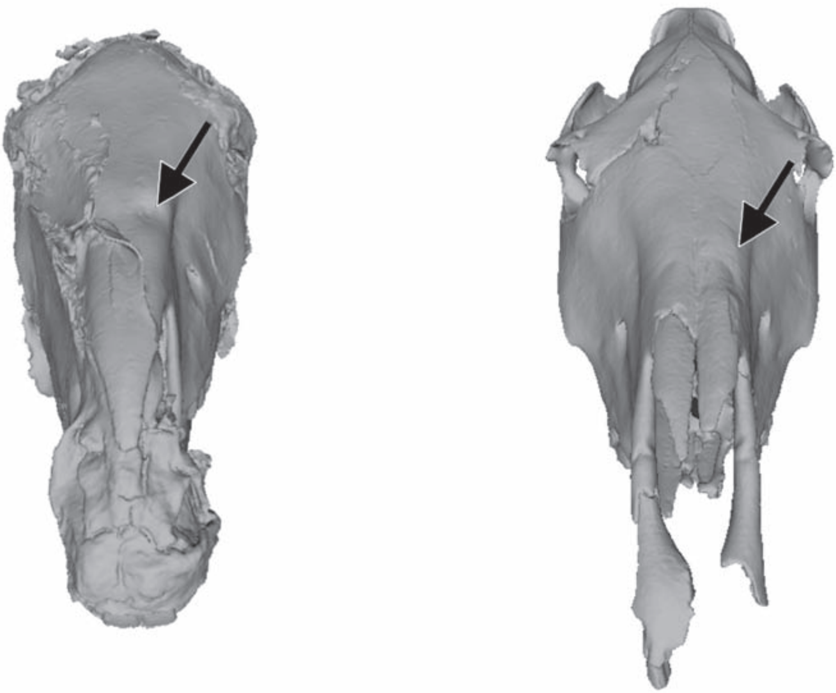

Figure 9.7. Asymmetric deformation to the nasal bones on a mummified horse dating to the Middle Ages from Ulaan-Uneet (left), and similar feature on a late Bronze Age horse from the site of Khushuutiin Gol in northern Mongolia (right).

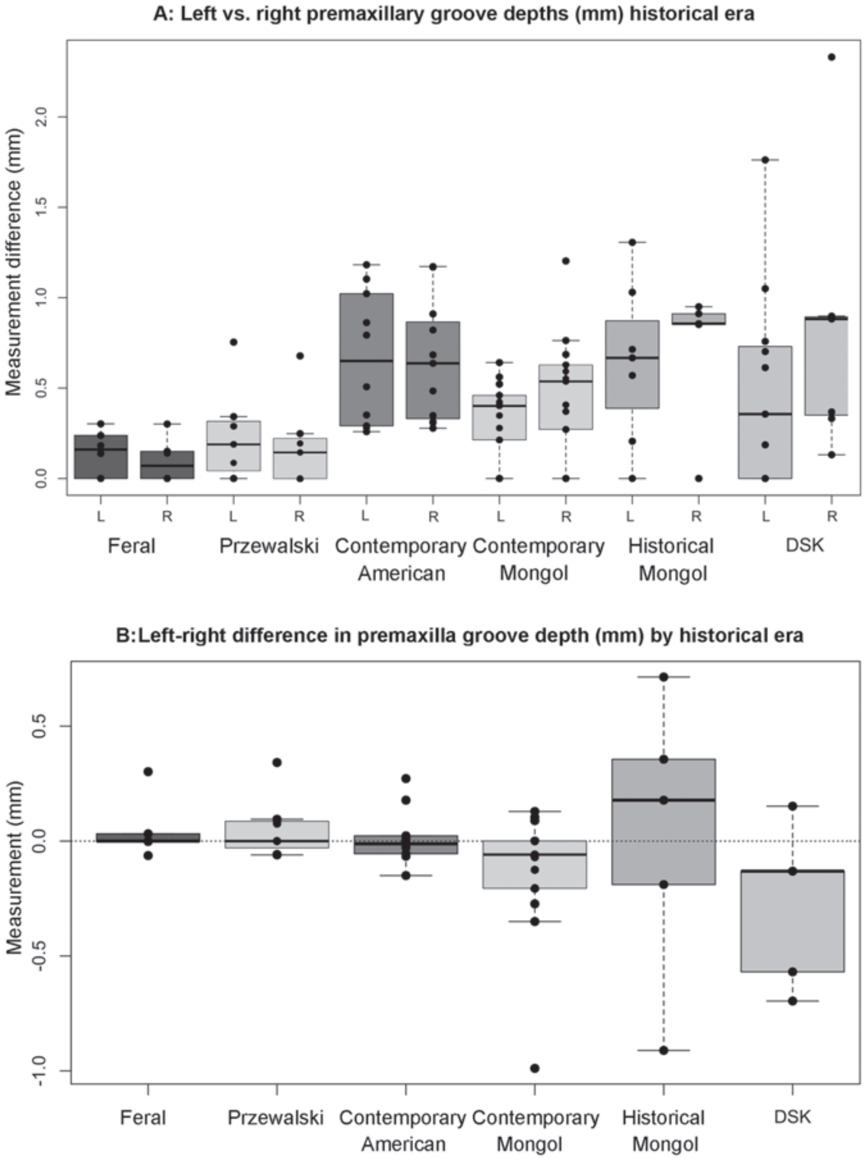

Figure 9.8. A: measured left vs. right maximum premaxilla groove depths for feral American horses (n=6), Przewalski horses (n=7), contemporary American horses (n=11), contemporary Mongolian horses (n=13), post-Bronze Age archaeological horses (n=7), and those from deer stones and khirigsuurs (DSK, n=12). B: left minus right maximum premaxilla groove depths for the same sets. Cases (black dots) above the dotted line indicate deeper grooves on the left side of the skull, while those below represent a deeper groove on the right. Specimens without both left and right premaxillary measurements were excluded from Figure 9.8B.

Among the studied sample of contemporary American domestic horses from museum collections, grooving to the exterior of the premaxilla is remarkably symmetrical, even among those with comparatively severe remodelling. The same trait also characterises the lateral grooves observed in unridden feral and captive wild horses. A one-way analysis of variance (ANOVA) between feral American horse (n=6), Przewalski horse (n=7), and contemporary American domestic horse (n=11) samples provides some evidence that the contemporary Mongolian horse sample (n=13) has more negative groove differentials (read: deeper right premaxilla grooves) than the other groups ($p \leq 0.10$). Moreover, a Bartlett's test for equal variance suggests that these four groups have different variances ($p \leq 0.01$), with the modern Mongol horse sample exhibiting the greatest variation in premaxilla groove depth. Because these samples were drawn from museum collections and opportunistic surface finds, it is unclear how reliably they may represent the larger populations. A test of sample normality in the statistical package R using the qqplot function shows a heavy-tailed distribution, suggesting that the assumption of normality underpinning these tests may not be entirely justified.

Only a handful of Late Bronze Age specimens had both left and right margins present and sufficiently preserved for analysis (n=4), foiling attempts at statistical comparison. However, three of these exhibited deeper grooves to the right premaxilla, and among all measured specimens (n=12), the mean depth for right premaxilla grooves (0.83 mm) was higher than that for left premaxilla grooves (0.49 mm).

9.3.3 Oral and bitting damage

Bitting damage on contemporary Mongolian horse specimens consisted primarily of severe, parallel-sided wear to the oral margin of the lower second premolar, similar to that noted by Bendrey (2007). Of the six total mandibular specimens analysed, four exhibited this type of damage, although there was no discernible pattern in the length or severity of oral enamel wear between the left and right. Two horses exhibited severe *in vivo* enamel chippings and erosion of the lower margin of the left P_2. We observed no instances of occlusal premolar bevelling in modern horses, but one specimen collected from Gobi-Altai province in southwestern Mongolia had a strange occlusal concavity on the oral portion of the lower left P_2.

Horse specimens from the Iron and Middle Ages exhibited a variety of tooth damage which may be related to metal bits. Observed damage included occlusal bevelling with even cementum and enamel wear, parallel oral enamel exposure on the upper and lower premolars, enamel chippings and cracks, and new bone formation on the mandible's lateral margin (Table 9.2). Oral enamel wear indicative of bitting was common on both the left and right lower premolars, all three cases of occlusal bevelling to the lower P_2 were more extreme on the left side. Several horses also displayed damage to the upper premolars, including concave wear of the upper occlusal surface similar to that linked by Johnson and Porter (2006) with bit-chewing (Figure 9.9a) and flat, even wear to both upper and lower premolars (Figure 9.9b). This occlusal damage removed a significant portion of the oral part of the tooth, and must have been caused by either intentional rasping/dentistry, or direct wear to the tooth margin during periods of extreme rein

*Table 9.2. Possible Bit-related oral damage among adult horses from post-Bronze Age archaeological contexts. U=upper, L=lower. *denotes deeper bevel on a tooth with no Greaves' effect (even enamel and cementum wear).*

Specimen	*Historical period*	*LP_2 Bevel*		*Greaves effect*	*Malocclusion caused?*	*Oral enamel wear on P2 teeth*		*Other*
		L	*R*			*L*	*R*	
NMM 013	Pazyryk (6th–2nd *c.* BC)	7.35	na	Yes	No	U	–	Upper occlusal wear (UL and UR P2)
NMM 071	Xiongnu (2nd *c.* BC–1st *c.* AD)	6.86*	5.37	Yes	No	U	U	Upper occlusal wear (UL and UR P2)
NMM 080	Xiongnu (2nd *c.* BC–1st *c.* AD)	0	0	No	–	L	U L	Concavity in LRP_2 oral margin
NMM 094	Xiongnu or Xianbei (1st–3rd *c.* AD)	0.66	0.79	No	–	L	–	Cracked enamel (LLP2)
NMM 011	Turkic (6–8th *c.* AD)	9.81*	8.22	Yes	No	L	L	Upper occlusal wear (UL and UR P2)
NMM 081	Turkic (6–8th *c.* AD)	6.83*	4.84	Yes	Unknown	–	–	–
NMM 082	Turkic (6–8th *c.* AD)	3.12	0.77	No	–	L	L	Bone formation (Left), Enamel chipping (ULP_2)

tension. Finally, one specimen displayed new bone formation to the diastema at the corner of the lower left P_2 (Figure 9.9c).

Previous analysis of bit wear in DSK archaeological samples showed little evidence of Late Bronze Age occlusal bevelling or other bitting trauma (Taylor *et al*. 2016). However, this study did reveal a high instance of *in vivo* chipping and cracking with asymmetric frequency. Nine of 46 DSK specimens exhibited non-taphonomic chippings to the left premolars, with only four specimens displaying a similarly damaged right premolar. One specimen, a horse from the site of Zeerdegchingiin Khoshuu in northern Mongolia, displayed chippings of identical size and placement to the oral margin of both the left and right lower premolar (Figure 9.10).

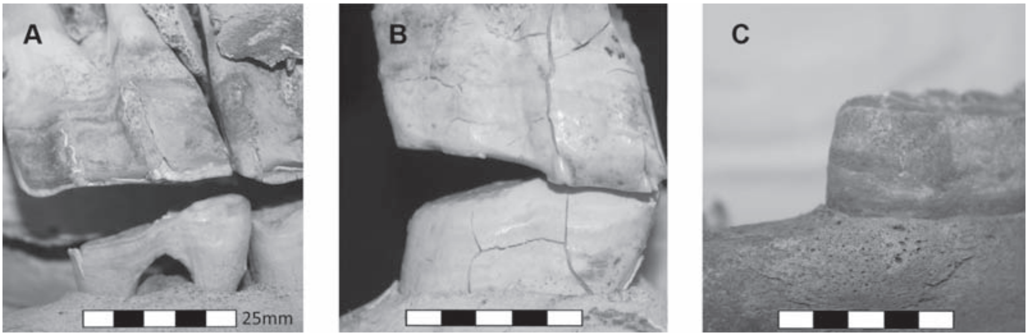

Figure 9.9. A: showing concave wear to the upper P^2 occlusal surface and flat beveling of the lower P_2 in a Pazyryk horse from western Mongolia. B: flat beveling of both lower and upper premolars in a Xiongnu period horse from western Mongolia. C: bone formation on the left mandibular exterior on a horse dating to the Turkic period, likely caused by bit use. Scale=25 mm.

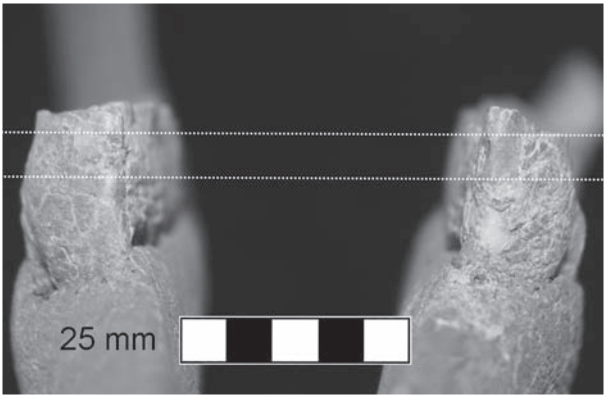

Figure 9.10. Identical enamel chips on the anterior surface of the lower second premolars of a horse from the site of Zeerdegchingiin Khoshuu in northern Mongolia, which may have been caused by a hard bar bit. Scale=25 mm.

9.4 Discussion

These data provide strong preliminary support for the idea that riding horses with a bridle placing chronic pressure on key areas of the nose and mouth produces asymmetric deformations to the equine skull, and therefore this practice might be identifiable archaeologically.

Nasal remodelling caused by a noseband was identified in contemporary Mongolian horses, but largely absent from the analysed sample of race, military, and farm horses from American museum collections. By itself, such deformation is not indicative of horseback riding, as it can occur on haltered but unridden animals, or those used for pulling carts or sleds (Taylor *et al*. 2016). Nonetheless, the presence of larger taphonomic holes on the left side of the nose are suggestive of preferential thinning, which may be related to asymmetric pressures during use. Horse skulls from archaeological deposits also showed left-sided deformation. A young horse recovered from a 10th century AD burial at the site of Ulaan-Uneet, in association with riding equipment, exhibited an especially extreme example. Another adult male horse also dating to this period, recovered from Bayan-Ulgii province, displayed a small depression on its left side. These observations, while small in number, are consistent with the predicted link between left-handed riding and cranial asymmetry.

Asymmetric premaxillary grooving – deeper grooves on the animal's right side – is also a feature of the contemporary Mongolian domestic horse sample, a result which can be plausibly linked to riding activity. This grooving is associated with a branch of the infraorbital nerve, and might develop in response to chronic pressure or inflammation caused by the bridle's cheekpiece during riding. A small sample of archaeological riding horses from Iron and Middle Age burials also showed more asymmetry than contemporary domestic and wild horses from American museum collections, although this pattern was less consistent with predictions in terms of deeper right premaxilla grooves. In early nomadic bridles, the large rigid metal, antler, or wooden bars flanking the bit on either side of the cheek probably placed even more substantial pressure on this area of the horse's anatomy on both sides of the face than do contemporary bridles, which may help explain this variability. A larger dataset will be necessary to clarify whether premaxillary asymmetry is indicative of broader trends in contemporary and ancient populations.

The dentition of 15 modern Mongolian horses analysed for this study shows evidence of regular contact between bit and premolar, but not asymmetric damage. Horses in this sample group exhibited severe wear to the oral margin of the second premolar, with morphology diagnostic of bit use. Despite extreme bit pressures observed on the teeth during our ethnographic study, none of the analysed specimens exhibited occlusal bit wear, with the exception of one localised concavity on the lower left P_2 that could have been caused by bit chewing. Modern Mongolian bits have a unique structure in comparison to their ancient counterparts – with large, curved canons that may alter the bit's position in relation to teeth under rein tension. This difference may minimise occlusal contact, and explain the comparatively high frequency of oral tooth damage in this group.

In contrast, several archaeological riding horses from the Iron and Middle Ages displayed severe, flat occlusal damage to the lower premolars, with more invasive bevelling on the lower left premolar. An expanded sample of historical horses from Mongolian contexts will help explore whether this asymmetry is attributable to horseback riding. Other kinds of tooth wear, including oral enamel exposure, upper premolar wear, and bone formation were also common in this group, although no obvious directional trends emerged. Two kinds of upper premolar bevelling identified here are also worth of further study, and could relate to bit chewing or incidental wear during mounted riding.

9.4.1 Horse monument at Arvaikheer

A key issue with quantitative comparison of contemporary and ancient horses is that of sampling bias. Most of the analysed horses interred in nomadic burials from the Iron Age and onwards were recovered along with bridles, saddles, stirrups, and other tack. Consequently, they may have been used quite intensively as both herding animals and war mounts. In contrast, contemporary animals recovered from the Mongolian countryside may not have been ridden as often, nor as hard as their historical counterparts. It is also likely that the rigid cheekpieces used in ancient bridles had a more severe effect on the horse's face than the simple rings or ring-with-bar configurations used today.

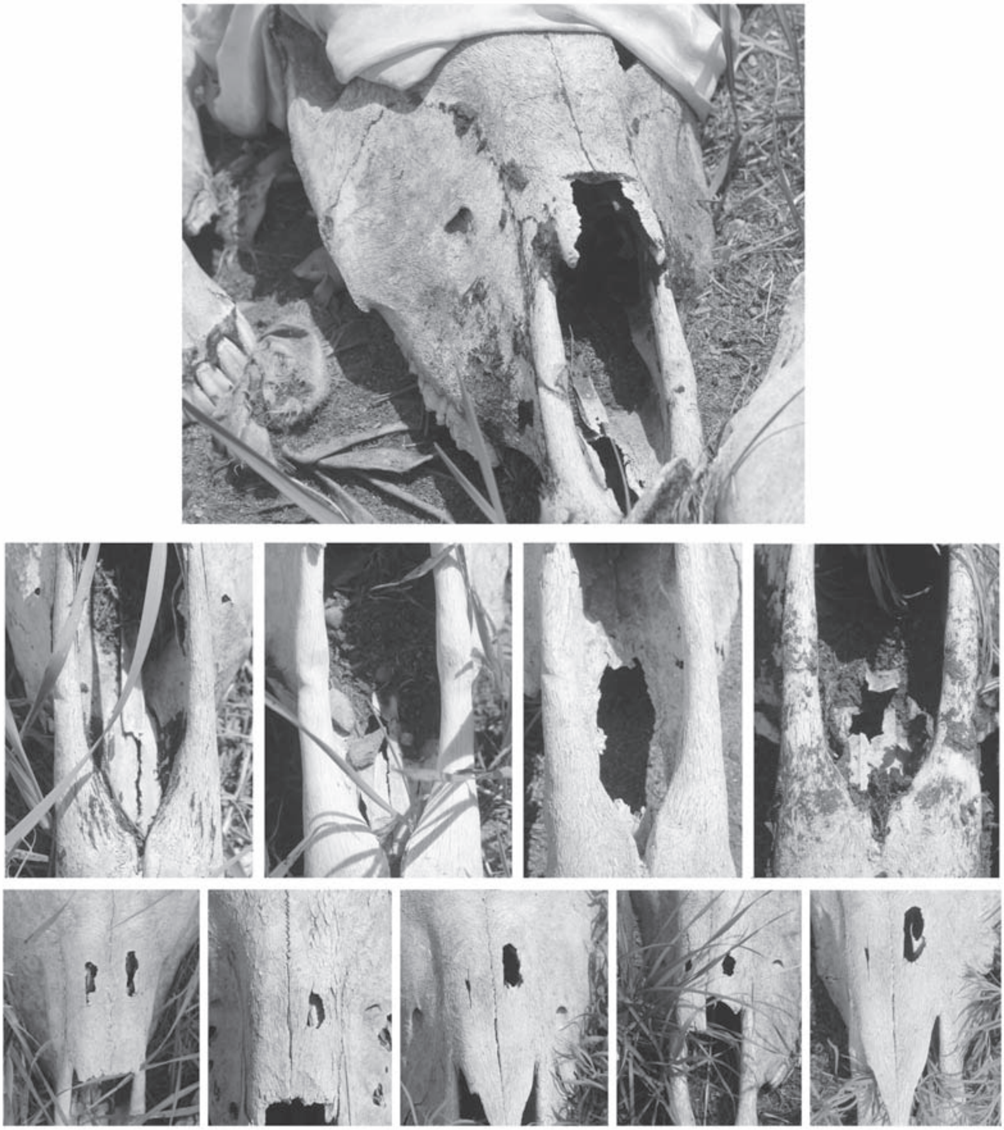

Figure 9.11. Racehorse skulls at Arvaikheer displaying premaxillary remodelling (top), and nasal thinning (bottom).

To check our results against a sample of intensively trained and ridden animals, we visited the racehorse monument near Arvaikheer in Arkhangai province, Central Mongolia. For many years, local people have placed the head of successful race horses, or favoured personal riding horses, in long rows behind the horse statues comprising the monument. Due to thick vegetation and differential preservation, the total number of horses at this monument is difficult to calculate, but we observed at

least 296 individual horse skulls, ranging from recently deceased to badly damaged or destroyed. These horses are revered – many adorned with special *khadag*, a kind of ceremonial scarf. Because of this, their skulls were not disturbed or handled from their original position. Owing to their variable states of preservation and visibility, quantitative conclusions cannot be drawn from this sample regarding the true prevalence of cranial changes.

Nonetheless, several inferences can be drawn from qualitative observations of Arvaikheer horse skulls. First, even allowing for taphonomic degradation, it seems that nasal deformations are not ubiquitous on Mongolian racehorses. We noted visible premaxillary grooving deformations on only ten animals, and only ten cases of demonstrable nasal remodelling or thinning. Skulls with visible premaxillae also had exposed and badly damaged nasal bones, while crania with intact nasalia were partially buried. Consequently, it was not possible to assess whether any specimens displayed both kinds of remodelling. Still, observed specimens exhibited consistent patterns in asymmetry which provide independent support for our hypothesis. Those horses with premaxillary remodelling visible to the naked eye all showed apparently deeper grooves on the animal's right side (Figure 9.11, top). Moreover, of the eight specimens with visible thinning of the nasalia, seven displayed appreciably larger holes on the left side of the nose (Figure 9.11, bottom). This suggests a pattern of greater bone thinning on the left side of contemporary riding horses. These results provide independent support for the idea that contemporary Mongolian horsemanship produces recognisable, asymmetric deformations to the equine skull.

9.4.2 Bronze Age patterns

In light of these finds, the asymmetric cranial bony changes identified on horses recovered from deer stones and *khirigsuurs* may be plausibly linked to horseback riding. The markedly asymmetric nasal deformation in the best-preserved DSK skull is noteworthy, and must have been caused by either left-handed rein tension, or an alternative source of consistent and asymmetric pressure on the equine skull. Sample size and preservation prevent robust quantitative comparison with modern samples, but the Bronze Age horses considered in this study also displayed generally deeper grooves on the right premaxilla similar to those observed in contemporary and historic Mongolian samples.

The analysed sample of Bronze Age Mongolian horses exhibited no occlusal bevelling, consistent with the idea that organic bits were used in the region at this time (Taylor *et al*. 2016). However, the analysed sample did exhibit a high frequency of *in vivo* chippings and cracks with more instances on the lower left premolar. This result could have any number of natural or taphonomic causes, but may relate to riding strategy. To crack the horse's exterior tooth enamel with such regularity, it is likely that at least some DSK bits were made of a solid bar of bone, rather than wood or leather. This inference is supported by two identically-placed chippings to the midsection of the oral margin of the lower second premolars on a horse from the site of Zeerdegchingiin Khoshuu in northern Mongolia (Figure 9.10), perhaps caused by a single contact event with a hard bar bit. If enamel chippings on Late Bronze Age

Mongolian horse teeth are anthropogenic, the strong left-biased asymmetry may be attributable to horse riding.

The practice of horseback riding in the DSK complex would have key implications for the development of nomadic culture and horse transport in eastern Eurasia. As most other conclusive traces of mounted horse riding date to the early 1st millennium BC (Drews 2004), DSK culture might have been among the earliest in eastern Eurasia to engage in reliable, widespread riding. Because this culture is also linked with the emergence of mobile pastoralism (Houle 2010, 180), evidence for DSK riding would support suggestions that early mobile herding in eastern Eurasia was linked to the development of horse riding (Beardsley 1953).

Future applications of the techniques investigated here will help evaluate hypothesised links between left-handed reining and asymmetric cranial deformations. Doing so will require an expanded sample of modern and ancient skulls, and detailed comparison with animals used to pull wheeled vehicles – to rule out the possibility that prolonged chariot use could produce similar results. Nonetheless, it appears that study of equine cranial asymmetry is a particularly fruitful line of inquiry for tracing the transition to mounted riding, requiring only prehistoric animal bone material. This approach may help resolve key debates related to the chronology of horse transport in other early Eurasian archaeological contexts, where skeletal remains are often the primary (or only) dataset available for evaluating ancient horse use. By comparing these data with horse remains from other historical periods, cranial morphology may expand the scope of archaeozoological inquiry to include new aspects of behaviour, such as transport type and riding style.

9.5 Conclusions

Ethnoarchaeological study among contemporary Mongolian herders raises the possibility that particular bridles and riding styles can produce asymmetric effects to the skull of the horse. Detailed comparison of modern and historical horse skulls suggests that left-handed reining with a direct noseband connection produces recognisable changes to the left side of the nasal bones and right margin of the premaxilla, which may be caused by horseback riding. Future research will be necessary to investigate whether such cranial changes also develop in the context of ancient chariot use. A small sample of horses from Bronze Age archaeological sites also exhibits these patterns, and hints at the practice of mounted riding in the eastern Eurasian steppes by the late 2nd millennium BC. Methodological refinement will move archaeologists closer towards reliable identification of mounted horseback riding in other prehistoric contexts, and improve our understanding of how equine transport shaped human societies.

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10. Where Have All the Mares Gone? Sex and "Gender" Related Pathology in Archaeological Horses: Clues to Horse Husbandry and Use Practices

Pamela J. Cross

Horses are important cultural markers, and their treatment within the archaeological record can provide information about human–horse relationships. While horse remains are often sparse, they are widespread throughout Eurasia and the horse is also one of the few animals to regularly receive burial treatment comparable to humans. The zooarchaeological study of horses has been surprisingly limited, particularly regarding palaeopathology. Horses from burials, coupled with the usually disarticulated remains from settlements, offer an underexploited resource for investigating human–animal relationships such as gendered horse use and husbandry practices. Discerning husbandry practices, and horse demographics in general, has been hampered by difficulties in determining sex ratios, particularly as horses are not very sexually dimorphic and those aspects of the skeleton most useful for sexing are often lost, making the identification of female horses particularly difficult. Palaeopathology potentially offers additional means of identifying the presence of females. Cultural gender attitudes towards horse use in early north-western Europe appear to have assigned females generally to reproductive roles and males to transportation work. These functions also appear to have had different care levels. It is proposed females were generally kept in broodmare herds which received minimal care, while males (most common in archaeological contexts) received more regular care for injuries and dental malocclusions. These care differentials may equate with pathology types and patterning which can provide additional skeletal clues regarding the sex of archaeological horses. In particular, evidence of poor dental care and/or the persistence of chronic laming pathologies appear more likely in female archaeological remains, and their presence may indicate female horses, even in fragmented assemblages.

10.1 Introduction

Since at least the Bronze Age, the control and use of domesticated horses has had profound impacts on human cultures (Anthony 2007; Kelekna 2009; Clutton-Brock 1992). The use of horses in warfare changed social and political realities for multitudes of peoples on every continent the horse was introduced (Olsen 2006; Bou 2009). In 1st millennium AD Eurasia, horsemen in Britain and elsewhere challenged the mighty Roman Empire on many fronts and had significant cultural impacts. The horseman, in

the form of the knight, came to epitomise the European medieval period. While horses have played such important roles in human societies for millennia, understanding how and where they were bred within non-literate and semi-literate cultures is especially difficult.

There are a number of difficulties in studying the skeletal remains of domesticated horses, particularly in Europe where, while pervasive, horse remains occur in very small quantities among settlement refuse. The domesticated horse, like the dog, appears to function in most cultures generally as a non-food-animal, so it is not surprising that horse bones are scarce amongst the usual food refuse remains which predominate in European assemblages. There is scattered evidence of dismemberment butchery of domestic horses in European archaeological assemblages, but the consumption of horsemeat appears to have been a very limited and was probably mainly ritual oriented, perhaps similar to traditions currently practiced amongst the Siberian Sakha (Takakura 2015, 121; Cross 2011; BBC 2009; Simoons 1994). There does not appear to be any evidence supporting horse dairying in most of Europe.

Horse bones amongst the typically disarticulated and fragmented assemblages at rural sites commonly comprise less than 10%, even at sites where they are described as common, and often comprise less than 5% of the identifiable bones (Cross 2011; Johnstone and Albarella 2002, 33–36; Albarella and Davis 1994; O'Connor 1994). The horse, however, is one of the few domesticates to regularly receive interment similar to those of humans and evidence of horse burials can be found on all inhabited continents. In Europe, both horse and human–horse burials have been excavated (Cross 2011; Antikas 2008; O'Connor 1994; Müller-Wille and Vierck 1970–1971; Bökönyi 1968, 34). Unfortunately, again, horse burials only comprise a very small percentage of burial populations, and, as regards this paper's focus, contain also predominantly male horses (Cross 2011; Dickson *et al*. 2011, 223–229; Antikas 2008; Daugnora and Thomas 2005; O'Connor 1994; Müller-Wille and Vierck 1970–1971; Bökönyi 1968, 34). The European archaeological record of identified female horse remains is tiny in the relevant literature.

The reasons for this dearth of female remains, which logically should comprise at least 50% of the equine population, may be two-fold. Firstly, there is the circularly interactive problem of few remains and poorly developed methods of identification. Secondly there is the potential existence of culturally determined husbandry/deposition practices which do not leave female skeletal remains in the investigated areas. The discussion here focuses primarily on the possibility of gendered horse husbandry/deposition practices.

Historical and archaeological evidence suggest in much of Europe that the roles played by horses were gendered during the 1st and 2nd millennia AD. Use-horses (for riding or draught) appear predominantly male, while the primary function of female horses was reproduction as dedicated broodmares. There are also indications of these broodmares having been kept in small herds and in many cases infrequently handled. This gender split is supported in early medieval Britain by historical data, such as the 11th-century Domesday books which list many holdings of one or two horses (generally considered male use-horses) and small instances of groups of female horses referred to as *equae silvestres* (forest mares) and *equae indomitae* (wild/untrained mares) (Edwards 2004, 21–51; Cathers 2002, 113, 121, 367–373, 470–513ff; Gladitz 1997, 141–166ff; Dent

and Goodall 1962). Females are also identified specifically as breeding stock in King Alfred's *c*. 890 AD law code which includes separate fines for horses (generally defined as male transport stock) and broodmares (Cathers 2002, 121).

That breeding herds in Britain were generally small is indicated by a number of documents. For instance, Dent and Goodall (1962, 162–164) discuss 101 horse sale transactions made by 53 owners at the 1631 Adwalton Faire (Yorkshire). The two largest lots held by single owners (John Lewis and Richard Oxley) were 15 and 14 horses respectively. Both lots were sold by chapmen who often appear to have acted as horse brokers, while the number of animals sold by farmer-breeders was typically one horse. In addition, Gladitz (1997, 166) compiled royal stud records which indicate breeding populations at these premiere breeders were *c*. 11–55 (average 26) horses, usually with only one breeding stallion (Table 10.1). Royal and state studs offered breeding stallion services to the wider population of small breeders and travelling stallions were periodically in use for small breeders without their own stallions (Lewis 1988/1989). Range-kept broodmare herds might include integral male studs, or stallions might be kept stabled with only seasonal inclusion in the broodmare herds.

A model may be found in the modern horse-focused Sakha culture (Siberians of Mongolian ethnicity), which adheres to gendered horse exploitation. Males are gender assigned as use-horses (primarily riding) and a few as breeding stallions, while females are gender assigned exclusively as broodmares and the riding of mares is taboo (BBC 2009; Takakura 2015, 29–31, 116). Sakha pastoral horse husbandry practices include small, predominantly female bands (6–20 females and one male stud) with seasonal gathering and corralling of bands. These include:

- spring foaling season with pregnant mares given additional fodder and some *c*. 2-year-old male juveniles castrated (in May) and removed for training as use-horses,
- summer branding and juveniles to be kept for breeding or culling identified,
- autumn (October–November) removal of juveniles of *c*. 6 months to separate foal group and some juveniles slaughtered at end of season/beginning of winter (Takakura 2015, 117–134).

Breeding horse bands are kept on pasture year-round, while use-horses (males) are kept in barns during the winter, pasture close to habitation during summer, and in enclosed paddocks with extra feed September–October, then range-kept during the winter (Takakura 2015, 117). Culled juveniles, barren females (culled for non-production) and retired male studs (by 20 years old) supply meat for important festivals (BBC 2009; Takakura 2015, 121–125). Two principal festivals feature horse meat (summer solstice and after autumn cull), as do some weddings and funerals (BBC 2009; Takakura 2015, 32–47, 107, 154–157). While the Sakha are obviously not the same as Late Iron Age or Medieval Europeans, aspects of their practices are based in biologically derived equine husbandry practices which may serve as a proxy for past cultures.

Control of the horse supply would have been important, particularly in times of warfare. Understanding where horses were bred and who controlled those areas can indicate important information about cultural or socio-political organisation. Zooarchaeology uses a number of methods to investigate past animal populations,

*Table 10.1. Horse populations at some 13th-century British royal breeding studs (Data: Gladitz 1997, 166). *Male juveniles at this site are 1–5 years old.*

County	*Royal stud*	*Total*	*Adult*		*Juvenile**		*% of total*		*Adult*
			F	*M*	*F<5yrs*	*M<3yrs*	*F*	*M*	*F:M ratio*
Warwick	Hampton	41	10	1	18	12	68	32	10:01
Warwick	Woodstock	31	27	4	0	0	87	13	7:1
Essex	Rayleigh	30	13	2	9	6	73	27	7:1
Merioneth	Ardudway*	65	54	1	3	7	88	12	54:1
Merioneth	Nant Conway	34	19	1	6	8	74	26	19:1
Gwynedd	Afloegion	24	12	1	10	1	92	8	12:1
Flint	Hope	48	21	1	20	6	85	15	21:1

including population demographics (sex, age and mortality profiles) body part representation, human modifications (butchery, tool-making), and taphonomic changes such as fragmentation and animal gnawing (Reitz and Wing 2004, 142–238). Two types of exploitation, particularly regarding domestic animals, are often identified: primary production and secondary production (Marciniak 2011; Halstead 1998; Sherratt 1983). Primary exploitation is the utilisation of dead animals, while secondary exploitation involves the renewable products of living animals (traction/transport, hair/wool, dairy). Horses are known primarily for their secondary exploitation, and evidence for breeding would follow secondary exploitation mortality profiles in the archaeological record (Marciniak 2011; Sherratt 1983).

An ideal or "natural" mortality profile for a breeding group would be characterized by the predominance of older females, a range of other age females, some juveniles and a very few adult males. However, the formation of actual horse bone assemblages is highly dependent on human practices. If pasture/range husbandry methods of predominantly female herds with young juveniles less than two years old are followed, and horses are not used as sources of meat or dairy, this horse population is unlikely to form part of the typical archaeological assemblages found within human settlement or funerary sites. Variants of pasture/range husbandry might include bringing females near parturition into paddocks closer to habitations, which would potentially bring remains of these animals into settlement site assemblages. Seasonal collection and ritual practices similar to those practiced by the Sakha described above might also introduce female and/or juvenile remains into settlement or funerary contexts (Cross 2011; BBC 2009; Takakura 2015, 32–47, 117–134, 154–157). Archaeozoological reports typically identify small numbers of either female or juvenile horses at most sites in Europe. Such low frequencies of females and juveniles would be expected in contexts reflecting this type of husbandry.

The author surveyed the Review of Animal Bone Evidence from Central England (RABECE) online-database (*c.* 500 reports and *c.* 400 sites) for reports with evidence of horses and further investigated sites which gave indications of females, juveniles and older horses (Albarella and Pirnie 2008). For the "Iron Age/Roman", "Roman", "Saxon",

and "Saxon/Medieval" time periods (total *c*. 276 records), *c*. 70% included some horse bone, but none identified any females remains and only 27 (10%) included juvenile remains. Twelve of those sites identified "older/aged" horses (4% of the 276 records). As indicated above, juveniles and older animals are also associated with secondary exploitation and potential breeding populations, but this discussion focuses on the identification of female horses in archaeological contexts in Europe, particularly early Britain. Further discussion of older and juvenile horses is beyond the scope of this article.

In zooarchaeology, the primary means of identifying potential breeding sites has relied almost exclusively on evidence of juveniles despite the fact that the major portion of the breeding population should be females. Currently, identified female horse remains form a tiny percentage of the already low percentage of horse remains from archaeological sites. Additional means of identifying females would increase our ability to assess and understand the control and breeding of horses.

As part of the author's PhD work on horseman identities and human–horse relationships in 1st millennium AD Britain, a number of possible patterns emerged in the distribution of pathological lesions. These suggested that human cultural perceptions of gender and occupation were applied to horses and also linked with their care (Cross 2017, 225–260). Dental pathologies, particularly those associated with malocclusion and the development of "hooks", sharp points, were probably corrected in many use-horses (predominantly males), but may have been allowed to persist in range-kept broodmares. As noted above, broodmares may have been little handled (*equae indomitae)*, which would have made care for injuries or dental adjustments essentially impossible. Significant laming injuries in use-horses would impair their function and quickly result in culling of the animal, probably before significant skeletal expression of pathology. Significant injuries and disabilities in little-handled broodmares may have been generally ignored as long as the disability did not interfere with their breeding function. These two areas of pathology are investigated regarding their expression in identified female archaeological horses, with some comparison of pathologies in identified males.

10.2 Materials and methods

In order to address these questions, the author examined modern and archaeological horse remains at a number of institutions, targeting identified females and pathological specimens of both sexes. The results of these visits, work conducted on site assemblages and a literature search form the materials in this study. The entire equid assemblage from one site, Sedgeford (Norfolk, UK) was examined and analysed on-site and at laboratories at the University of Bradford (Archaeological Sciences), as were the modern specimens (Table 10.2). The other horse materials examined were analysed at museums where they are curated (Table 10.2). Additional case studies were analysed from excavation documents and publications (Table 10.3). The Sedgeford assemblage was analysed in detail for the author's MSc thesis and reanalysed during subsequent PhD studies (Cross 2017; Faulkner *et al*. 2014a, 2014b; Cross 2009). The set of modern horses are kept in the author's personal collection, obtained primarily through an eight-year relationship with the University of Aberystwyth, Institute of Biological,

*Table 10.2. Horse specimens examined and analysed. *Approximate dates (?) given in centuries AD, absolute dates (documented/radiocarbon) given in year-of-death or calibrated range. Abbreviations: SHARP=Sedgeford Historical and Archaeological Research Project; UK=United Kingdom; NL=The Netherlands; HU=Hungary.*

Specimen	*Site, country*	*Reference*	*Curation*	*Date**
UoW-Son	Aberystwyth, UK	n/a	Cross Equine Skeletal Collection	2013
FN511	Sow Kiln, UK	Cross 2009, Johnson 2006	Ingleborough Archaeology Group	15th–17th?
NC208	Sow Kiln, UK	Cross 2009, Johnson 2007	Ingleborough Archaeology Group	15th–17th?
ERL104-4026	Lakenheath, UK	O'Connor 2002	Suffolk C.C. Archaeology Service	cal AD 490–535 (90%)
EqS7672	Sedgeford, UK	Cross 2009	SHARP	cal 111 BC–AD 60 (95%)
EqS0025	Sedgeford, UK	Cross 2009	SHARP	cal AD 670–820 (95%)
EqS2012	Sedgeford, UK	Cross 2009	SHARP	?
SH98-0088	Sedgeford, UK	Cross 2009	SHARP	?
Add'l Bone	Sedgeford, UK	Cross 2009	SHARP	?
M17_Eq	Sutton Hoo, UK	O'Connor 1994	British Museum	cal AD 580–660 (95%)
ILA79	Miles Lane, UK	Cross 2014	Museum of London Archaeological Archive	2nd?
Oudemolen 1	Oudemolen, NL		Nuis Archaeological Depot	16th?
73.8.140	Tiszafüred–Majoros, HU		Hungarian National Museum	6th–9th?

Environmental and Rural Sciences (IBERS; https://www.aber.ac.uk/en/ibers/about-us) and a local Welsh Section A Mountain Pony breeder (Cross 2017). The portion of the collection utilised in this paper represents a set of skeletons with a known life history, dissected and prepared by the author (Tables 10.2 and 10.4). The ponies were primarily pasture-paddock kept in small herds (broodmares and a single male stud and separate weanling and juvenile groups). The Cleveland Bay stallion was owned by the same breeder and kept in the same way, but was over-wintered in a barn for the last few years of his life due to increasing disability. None of the specimen animals were ridden or used for draught. Other modern breeding horse groups were also observed by the author at a number of small holdings in Yorkshire and Wales, one of which included a severely lame breeding female.

The samples identified and principally discussed in this study are detailed in Tables 10.2 and 10.4 (specimens analysed) and Tables 10.3 and 10.5 (examples from

*Table 10.3. Comparative data on horses analysed from the literature.*Approximate dates (?) from authors given in centuries, radiocarbon dates in calibrated range.*

Specimen	*Site, country*	*Reference*	*Century*
Whitby21496	Whitby, UK	Baker 2003	19th–20th?
Sindos 3	Sindos, Greece	Antikas 2008, 2011	4th BC?
Blewburton 1	Blewburton Hillfort, UK	Bendrey *et al.* 2010	1st BC?
F41	Ranutovac-Meanište, Serbia	Bulatović *et al.* 2014	9th–1st BC/ Iron Age?
F14-1077	Icklingham, UK	Levine 2000	cal AD 100–320
Illerup 1	Illerup, Denmark	Dobat 2014	3rd–5th?
Illerup 2	Illerup, Denmark	Dobat 2014	3rd–5th?
Illerup 3	Illerup, Denmark	Dobat 2014	3rd–5th?
V-G29	Magdalenskagora, Slovenia	Bökönyi 1968	Hallstatt/Iron Age?

the literature). The specimens examined represent 13 horses (six female, six male, one unsexed). Specimens from the literature represent nine horses (four female, five male). Specimen IDs used are those assigned by the excavators or reports, or are comprised of the site name and a numeric. Dates included are context derived (denoted with (?)) or verified by historical record or radiocarbon dating. The curation field indicates the institution/location where the materials were when examined.

Methods used in the skeletal sexing and ageing were based on non-metric traits of the pelvis, dental sex differences (presence of canines more common, over 75% in males), dental development and wear, and epiphyseal fusion described in Sisson and Grossman's anatomy of the domestic animals (Getty *et al*. 1975; Brown 1883). Osteological methods for sexing and ageing were also informed by a background in standard human osteological methods such as Buikstra and Ubelaker (1994) and Scheuer and Black (2000). Supplemental data from zooarchaeological, husbandry and veterinarian literature sources were also utilised (Evans *et al*. 2007; Wilson *et al*. 1982; Richardson *et al*. 1995; Rivington *et al*. 1777).

10.3 Results

The results of the analysis are presented in Tables 10.4 and 10.5. Additional details on pathological lesions are given within the Discussion section. Among the horses examined, six females were identified (absent or vestigial canines, pelvic morphology). For the examined specimens (Table 10.4), there were no indications of mandibular P_2 beveling commonly associated with bit-wear, but two had uncorrected malaligned teeth resulting in uneven wear (one a known pasture-kept broodmare). The uneven wear of the modern pasture-kept female (UoW-Son), included minor wear of the mandibular P_2 teeth, which has also been associated with bit-wear in archaeological horses (Figure 10.1). In this horse, the wear is clearly due to points (or hooks) formed on the maxillary P_2 teeth. Three other females had significant pathological changes in the appendicular skeleton. Two of the horses, one

Table 10.4. Results of sex, age and pathological lesions of the horses examined and analysed.Abbreviations: F=female, M=male, Age in years, N/O=not observed; Y=yes; N=no; R-/L-=right and left; P=premolar; M=molar; I=incisor; P2= mandibular premolar 2, unless specified as maxillary (max); CV,TV,LV,SV=cervical, thoracic, lumbar and sacral vertebra.

Specimen	*Sex*	*Age*	*Dental*	*Spinal*	*Limb/Pelv*	*Lame?*	*Bitwear?*	*Notes*	*Associated bone group type*
SH98-0088	?	Adult	N/O	N/O	N				Limb
UoW-Son	F	10	Y	N	N/O			Uncorrected malalignment P/Ms	Complete
FN511	F	10+	N/O	N/O	N/O			Uncorrected malalignment - I2 (max)	Partial (CV1, R-pelvis, femur)
Oudemolen 1	F	12+	N/O	N/O	Y	Y		Patellar luxation	Complete
NC208	F	7+	Y	N/O	Y			Ossification of pubic tubercle ligaments	Partial (skull, CV-SV, pelvis, hind limbs)
EqS2012	F	Adult	N/O	N/O	N/O				Partial (pelvis)
Tiszafüred-M1	F	Adult	N/O	N/O	Y	Y		Ilium fracture	Complete
ERL104-4026	M	5–6	N/O	Y	Y			Minor limb/spine	Complete
EqS7672	M	5–6	N/O	N/O	N/O				Complete
EqS0025	M	5–6	N/O	N/O	N/O				Partial (axial/pelvis)
M17_Eq	M	5–6	N/O	Y	N/O			Minor LV5	Complete
ILA79	M	7–8	Y	Y	N/O		Y	P2 bevel, TV-LV ossification/fusion (fall)	Complete
UoW-Bas	M	19	N/O	Y	Y	Y?	N	Vertebral+pelvossif/ fusion	Partial (TV-SV, pelvis, limbs)

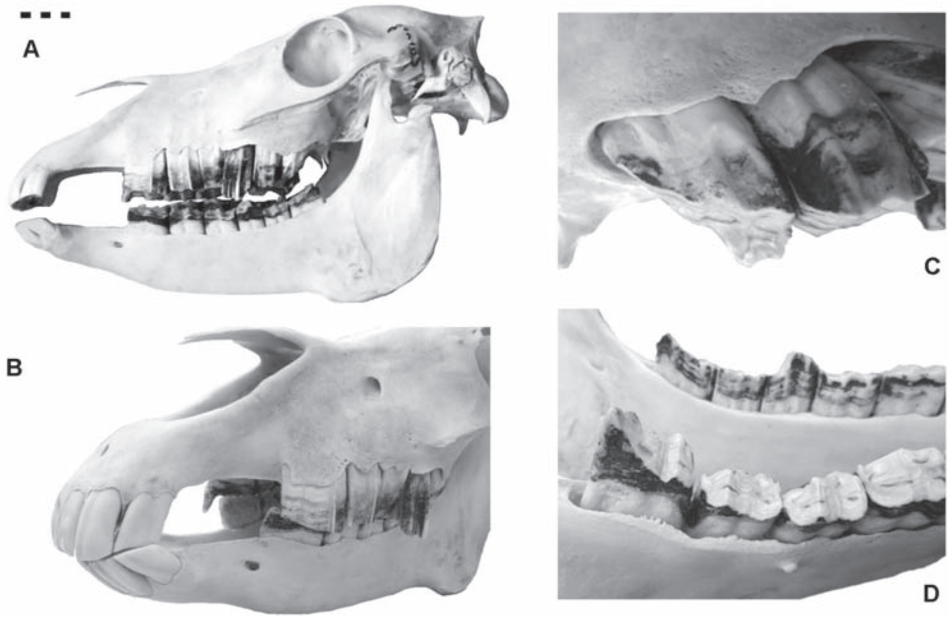

Figure 10.1. Modern pasture-kept broodmare (UoW-Son) with significant dental malalignment and evidence of gingiva infection in the alveolar bone. Note the formation of points in the first and last Cheekteeth and compensatory wear on the opposing second premolar and third molar teeth. A: left lateral view; B: left oro-lateral view; C: right lateral view of maxillary molars; D: right lateral view of mandibular molars. Scale=5 cm (Photos: author).

with a patellar luxation and the other with an ilium fracture, were without doubt significantly lame after the injuries.

Pathological lesions in the five males identified (using the evidence of canine development and pelvic morphology) included some minor osteophytes on the limbs and spine. Two individuals showed more significant spinal pathology, one of which also had both mandibular and maxillary P2 bevelling. The modern male (UoW-Bas) had significant ossification of soft tissues throughout the spine and pelvis, including a general distribution of enthesophytes and blastic modification of the ischial region of the pelvis suggesting an injury. This horse was a large, aged (19 years), modern carriage/draught stallion used occasionally for breeding. Despite the pervasive osteological changes, his movement was stiff but only occasionally suggestive of significant lameness.

Among the horses reviewed in the literature (Table 10.5), four females were identified displaying pathological deformities. Two had striations on the mandibular P_2, and one also had minor changes to the mandibular diastema indicating reactions to infection or injury, which Bendrey (2007) suggests may be linked to bit-wear or bit-related trauma. One female (F41) had extensive spinal changes, including ankylosis and ossification of soft tissues and coxoarthrosis (right femur) indicating the horse was

Table 10.5. Results of sex, age and pathology. Comparative horses from the literature. Abbreviations: F=female, M=male, Age in years, N/O=not observed; Y=yes; N=no; R-/L-=right and left; P=premolar; M=molar; I=incisor; P2=mandibular premolar 2, unless specified as maxillary (max); ManD= mandibular diastema; CV,TV,LV,SV=cervical, thoracic, lumbar and sacral vertebra; MC=third metacarpus; Ph=phalanx. Ages are given in years.

Specimen	*Sex*	*Age*	*Dental*	*Spinal*	*Limb/Pelv*	*Lame?*	*Bitwear?*	*Notes*	*ABG Type*
F41	F	4.5	Y	Y	Y	Y	Y?	Minor ManD/P2 striation, TV10-LV1 + limb arthrosis/osteophytes/ fusion	Complete
Blewburton1	F	6	Y		Y		Y?	P2 striation, minor L-MC3-Ph1	Complete
Whitby21496	F	12+	Y	Y	Y	Y?	N	Uncorrected malaligned P/M, vert ossification/fusion, exotoses	
Sindos3	F	11–12	N/R	N/R	Y	Y		Unreduced L-MC3 fracture	Complete
Illerup2	M	7			Y			Weapon trauma	Partial (no hind limbs)
V-G29	M	9	Y				Y	P2 bevel	Complete
Illerup1	M	10	Y		Y		Y?	Minor ManD, weapon trauma	Complete (no MC-Ph)
F14-1077	M	4–5	Y	Y	Y	N	Y?	Uncorrected overgrowth P2 (max), P2 bevel, fracture TV9, Tarsal 1-2 fused	Complete
Illerup3	M	8–10	Y		Y		Y	P2 bevel, weapon trauma	Complete

likely significantly lame. The well-healed but unreduced limb fracture of the Sindos3 female would also have resulted in significantly lameness. Whitby 21496, a large, aged and possibly draught breed female had pathological changes somewhat similar to those of the large, aged light draught breed male (UoW-Bas) noted above. She was likely stiff in movement, if not lame. The fourth pathologically affected female (Blewburton 1), was also aged but showed only minor tooth wear, limb and spinal pathologies. The five male horses with pathology included three with P2 beveling, one with minor diastema changes and one with a spinous process fracture of the 9th thoracic vertebra.

10.4 Discussion

10.4.1 Dental pathology: Care differences by sex and use

There are two aspects of dental pathology which, following the use-model discussed above, should vary according to gendered use and care of horses. Female breeding stock, associated with little or no dental care, should present more examples of uneven tooth wear, due generally to uncorrected malocclusions and often accompanied by alveolar bone pathology suggesting gum disease. Male transport stock, associated with active dental care, is less likely to have evidence of long-term significant oral pathology and may show evidence of corrected malocclusions, particularly of the second premolars, which is currently more generally considered bit-wear.

10.4.1.1 Female breeding stock – dental pathology

If as postulated, female horses were gender-designated as breeding animals and kept in pastures, woodland or heath areas with less handling, many oral pathologies were likely left untreated. Horses from archaeological sites displaying signs of significant dental wear pathology may then be more likely to represent these breeding females. Some examples of malocclusion and other pathological lesions in the dental system were observed by the author amongst modern breeding herds in the UK (Figure 10.1).

Malocclusions may develop in all horses, and the formation of simply pointed teeth, particularly in the P2 and M3 are common. More severe malalignments are less frequent and all can be managed with dental intervention. Left untreated, malalignments tend to deteriorate and are often associated with gingival infections due to food trapped between irregular teeth. Periodontal disease generally progresses from the loss of soft tissue between the teeth, which creates more pockets to trap food and leads to chronic inflammation which spreads both buccally and lingually and may result in pitting and resorption of alveolar bone (Colyer *et al*. 2003; Brown 2011, 563).

No early archaeological examples of such dental pathology in female horses have been identified by this author, but the modern female (UoW-Son), and the aged (12+ years) 19–20th-century horse (Whitby 21496) both show these types of dental lesions (Figures 10.1–10.2) (Baker and Daulby 2003). UoW-Son also displays the common formation of P2 and M3 points and the wear or beveling of the opposing P2 and M3 teeth (Figure 10.1).

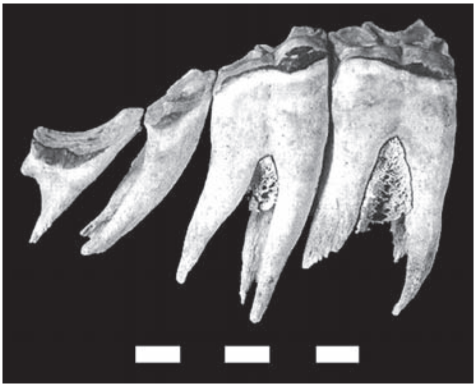

Figure 10.2. Teeth of a 19–20th-century mare (Whitby 21496) with significant uneven dental wear in all molars (M1–M3). Right mandibular M_1–M_3 shown. The M_3 (left) is worn below the cingulum and has fractured at the root base (Photo: © Historic England; Baker and Daulby 2003).

10.4.1.2 Male use-stock – dental pathology

Research suggests that in Britain, and much of Europe, male horses were primarily used for riding and draught. Reflecting their importance, these transport-horses received additional dental care (Fahrenkrug 2005, Kertész 1993, 13). Of the archaeologically recovered male horses reviewed or examined by this author, no significant dental pathology similar to that described above in females was observed. However, some horses have what is described as "bit-wear". Bit-wear is a common archaeological interpretation of tooth-wear in the form of anterior bevelling of the second premolar (P2), and often only describes the mandibular P_2s without reference to the opposing maxillary teeth (Bendrey 2007; Brown and Anthony 1998; Dobat *et al*. 2014; Levine *et al*. 2002). An alternative interpretation of bevelling of the P_2 is abnormal occlusal-wear from the opposing P^2, and/or bevelling of an overgrown P_2 as corrective equine dentistry (rasping of point). The archaeological horse examined by Levine *et al*. (2002) is an example of uncorrected bevelling of the mandibular P_2 by overgrowth of the maxillary P^2. Overgrowth of the maxillary P^2, in the form of a sharp hook which then naturally bevels the opposing mandibular P_2, is one of the most common equine dental disorders (Brown 2011).

Becker in 1945 (quoted in: Brown 2011) found enamel overgrowths in over 90% of 32,000 cavalry horses examined. Tooth overgrowths develop due to the dental morphology (the mandibular arcade is straighter and significantly narrower than the maxillary), and may also be influenced by individual chewing patterns and feed types. Less occlusion contact when masticating softer feeds can encourage the development of sharp enamel points. Sharp points (hooks) typically form on the buccal aspect of the maxillary teeth and on the lingual aspect of the mandibular teeth. Hooks on the maxillary P^2 may occur in tandem with mandibular hooks on the M_3. These hooks can cause soft tissue injury and pain in the temporo-mandibular joint, both of which may lead to behavioural problems when handling a horse, especially when using a bridle.

Dental treatment of horses has existed for centuries and can be attested in the literature from at least from the 6th century AD, and the elimination of enamel points by means of filing the teeth (sometimes called floating) to restore an even occlusal surface has long been a practice in horse care (Fahrenkrug 2005, Kertész 1993, 17). In addition to files, hammers and chisels were also used to break off sharp points and could result in inexact breakage and sometimes serious injury (Fahrenkrug 2005). Use of a chisel may explain the morphology of the maxillary P^2 of the male RIA horse at

the Museum of London (Figure 10.3) identified as showing bitwear (Armitage and Clutton-Brock 1986), also examined by the author. The maxillary P^2 shown appears to have had an excessive portion of tooth removed, a typical problem when hammers or chisels were used to break off points.

Figure 10.3. Possible human modification of the second premolar (P2) of a young adult male horse (ILA79) to correct a maxillary point which bevelled the opposing mandibular P_2. Left oro-lateral view. Roman period horse on display, Museum of London (Photo: author).

A brief review of the literature suggests bit-wear or modification of the P2 teeth appears to be found almost exclusively in male horses (Dobat *et al*. 2014; Stead *et al*. 1991). In addition to ILA79 noted above, the following examples are typical. Of the Iron Age horses discussed in detail by Bökönyi (1968), three were identified as males, of which one (V-G29) from Tumulus V had mandibular P2 bevelling. Many of the maxillary P^2 teeth in the horses depicted in Bökönyi (1974, 278–289) are bevelled or suspiciously smooth on the occlusal surface, which may suggest they were treated. Unfortunately, the mandibles are not shown for comparison. Levine *et al*. (2002) discussed three horses with bit-wear or P2 bevelling, one was unsexed, but the other two were identified as male. One was an aged male with mandibular P_2 bevelling and flat opposing maxillary P^2 teeth. The other (F14-1077) was a young male and illustrates morphology-caused bevelling via overgrowth of the maxillary P^2, certainly not bit-wear (Levine *et al*. 2002, Clutton-Brock 1974). Two of the four male horses discussed by Dobat *et al*. (2014) are described as having pathology associated with bit-wear. However, one (Illerup 1) only has minor osteological changes to the mandible in the area of the diastema, which may be due to any irritation of the tissue, so is inconclusive. The second (Illerup 3) is reported to have the more accepted bevelling of the mandibular P_2s, however there is no indication that the maxillary P^2s were examined for overgrowth (Dobat *et al*. 2014).

Two horses found with bit-wear in the literature reviewed were identified as female (Bendrey *et al*. 2010, Bulatović *et al*. 2014). The Iron Age horse (Blewburton 1) was part of a burial assemblage including a human (originally identified as a man, but reassessed as a probable woman) and a dog from Blewburton hillfort, UK (Bendrey *et al*. 2010). The second, a young adult (F41) Iron Age horse, was buried in a circular pit near an Early Bronze Age cremation cemetery (Bulatović *et al*. 2014).

If the theory associating males and not females with P2 human-modification (either as bit-wear or abnormal wear and rasping) is correct, then what would explain its presence in these two females? Before addressing an alternative interpretation, two questions would need to be addressed. The initial question is whether the sex identification is

secure. The second question is whether the P2 modification may be natural rather than due to human modification.

Both horses were deemed female based on pelvic morphology described in Sisson and Grossman 1966[1] (Getty *et al*. 1975) and the presence of vestigial canines which appear to occur predominantly in female horses, though currently there are no supporting studies. This is generally a reasonable basis, but none of the osteological methods can provide absolute sex identification. Essentially only a DNA test would answer the question of sex unequivocally, so the horses could be male.

Perhaps more importantly, whether the P2 modification on these two horses is actually due to humans is very debatable. Neither horse has conventional bevelling to the P2, but only a narrow band of enamel exposure. Such minor changes in the tooth surface could result from a myriad of causes, as Bulatović *et al*. (2014) noted. Indeed, chemical analysis of the tooth surfaces looking for metal (bit or rasp) residue returned results consistent with dental tissues. The authors concluded this indicated use of an organic bit, but it may simply mean these striations are unrelated to bits (or rasps).

10.4.2 Significant laming pathologies: male/female care differences

While bony changes to horse limbs are relatively common, pathologies indicating chronic, serious lameness are less evident in the archaeological record. Examples which occur may be more likely to indicate female horse breeding populations, where foal production can be continued in spite of chronic lameness. The most common horse limb deformities in archaeological specimens are ossification/fusion of the auxiliary 2nd or 4th metapodials (splint bones) to the 3rd (main) metapodium, a mild anomaly, and fusion within the carpal or tarsal complex (spavin). Neither are associated with serious long-term lameness (Bendrey 2010, Daugnora and Thomas 2005). Five archaeological cases with significant chronic lameness are identified here, all female from burials of complete horses. The examples come from all over Europe and have been contextually dated: *c*. 4th century BC (Sindos 3, Macedonia), Iron Age (F41, Serbia), *c*. 7th century (73.8.140, Hungary), *c*. 16th century (Oudemolen 1, Netherlands), and *c*. 19th century (Whitby 1, England).

Antikas (2008) identified a female (Sindos 3) from a Macedonian cemetery with a healed, badly fractured third metacarpal (cannon bone). The bone healed grossly misaligned and attests to the survival of the horse for some time despite being severely lame. Such an injury, especially in the front limb, would make the horse unusable for riding or draught work, and "breaking a leg" continues to be a well-known death sentence for working horses. A mid-shaft break is the most common long bone fracture, and typically is the result of inter-horse aggression of pastured animals (Brokken 2015).

Another female (73.8.140) came from a large Avar cemetery at Tiszafüred in Hungary, which also included numerous horse burials. The horse in question had a displaced healed fracture of the ilial wing (Figure 10.4). This is the most common type of pelvic fracture, as the ilium projects prominently (point of hip on the exterior of the horse), especially in broodmares (Colahan and Whitton 2014; Axe 1905). Such fractures usually result in severe lameness, significant muscle atrophy and hip asymmetry, but are not life-threatening.

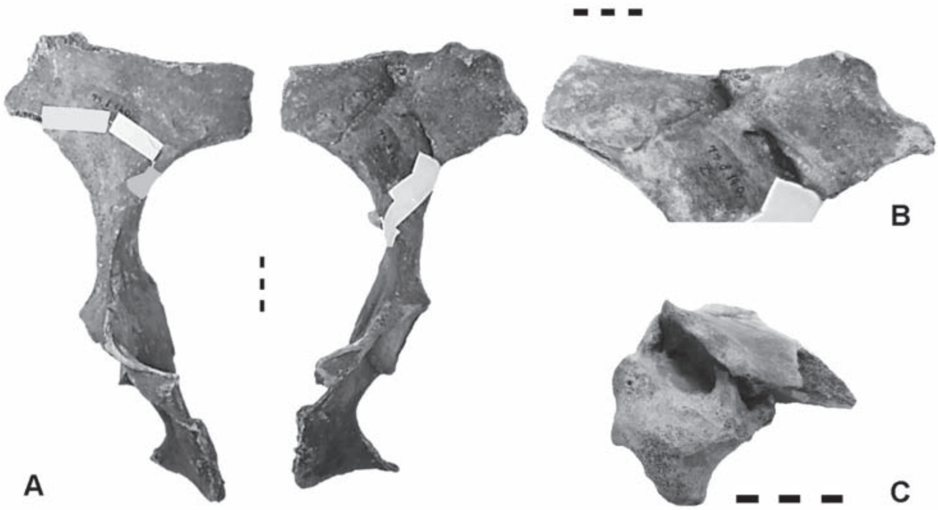

Figure 10.4. Female horse (73.8.140) from Avar period cemetery TiszafüredMajoros (Hungarian National Museum) with healed pelvic fracture. A: full cranio-ventral view; B: ventral view of the left ilium fracture; C: medio-ventral view of the same fracture. Scale=5 cm (Photo: author).

The female (Oudemolen 1) from a pit burial in Oudemolen had normal tooth wear. This mare suffered a severe, uncorrected patellar luxation in the left stifle joint with subsequent blastic deformation of the patella (ossification of the fibrocartilage and other soft tissues) and evidence of severe osteo-arthritic wear (eburnation and scoring) of the articular surface. Similar, corresponding changes in the distal articular surface of the femur, and to a lesser extent on the proximal end of the tibia, were also present. The degree of ossification and eburnation on the femur and patella indicate long-term survival of this horse after the original dislocation injury (Figure 10.5). Like the aforementioned horse from Macedonia, this mare would have been overtly lame.

The female horse (F41) reported by Bulatović *et al*. (2014) had extensive spinal changes, including ankylosis and ossification of soft tissues with focal trauma at the 14th thoracic vertebra. In addition, this female also showed evidence of coxoarthrosis in the right femur, at least one possible healed right rib fracture and other degenerative limb changes, surprising in such a young – only 4 or 5 years – horse. The authors associate the spinal pathology with riding, but such a link is tenuous: the animal's age, potentially its sex, and the extent and patterning of the pathological changes appear more consistent with a major traumatic event such as a fall or blow and subsequent skeletal responses (Bartosiewicz and Bartosiewicz 2002; Levine *et al*. 2000; Harris 1977). The degree of pathological deformations in the vertebral column and limb indicate this horse must have been severely lame.

The 19–20th-century horse (Whitby 21496) included dental anomalies and osteological changes which may be associated with lameness. The horse was identified as a female draught-breed (12+ years old) from a pit burial in Whitby, UK (Baker and Daulby 2003). The horse was quite large (*c*. 1.7 m) and robust. The pathological deformations

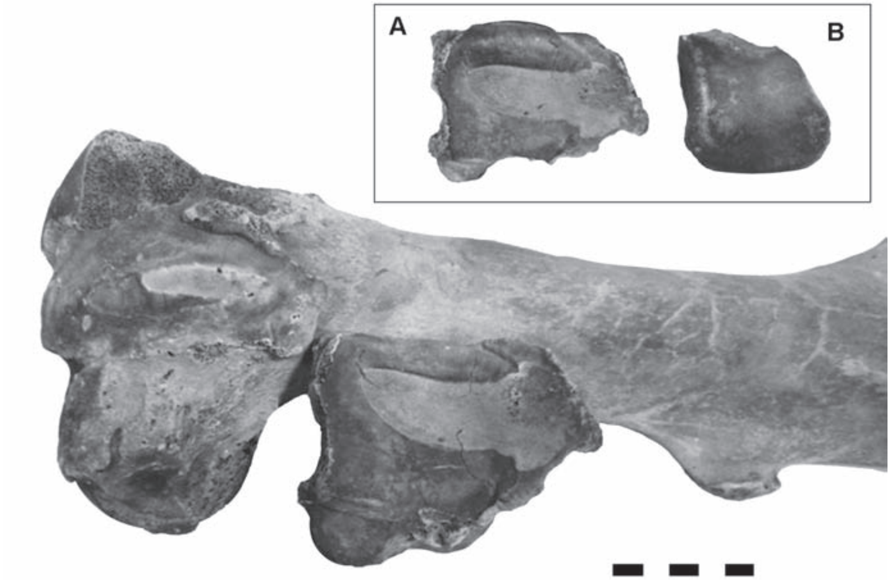

Figure 10.5. Evidence of severe patellar luxation in a female horse c. *16th century Netherlands (Oudemolen 1). The anterior view of the left femur distal articulation and patella. Both show extensive osteological changes, including soft tissue ossification and eburnation due to a long-term uncorrected dislocation. Insert A: pathological and B: normal patella. Images rotated 90º clockwise relative to natural position. Scale=5 cm (Photo: author).*

and dental wear described suggest a horse possibly closer to 20 years of age. Dental pathology included some extreme uneven wear of the molars and evidence of caries and gingival infection. There was no evidence of bevelling of the P2s. Osteoarthritic changes to the phalanges and a large number of vertebral exostoses suggest this horse was lame. This type of vertebral deformation is more commonly found in males, but very large horses may be more prone to osteophytic growths and arthropathy, due to additional stresses and possibly genetic disposition as well as hormonal differences.

These five archaeological examples of mares with evidence of poor dental maintenance and/or laming pathologies obviously represent a very small sample. In addition, the absolutely secure identification of these horses as females remains a problem. However, these case studies provide initial evidence supporting the theory that chronic laming pathologies, particularly those involving metapodial or pelvic fractures, and/or evidence of poor dental care are most likely to occur in female horses.

10.5 Conclusions

Female horses and breeding populations are almost invisible in the archaeological record of domesticated horses in Europe. Archaeological horse burials, one of the most commonly analysed incidences of skeletal remains, represent almost exclusively male horses. The disproportional ritual deposition of these horses in itself suggests

differential attitudes towards the "appropriate" roles of male and female horses. The most likely sources for evidence of females and horse-breeding areas are farm and settlement assemblages, which are typically too fragmented to easily identify the sex of individual animals for establishing sex ratios. The pathological changes identified here can provide additional methods to help establish the possible presence of female horses, and will contribute to our understanding of how people used and managed this important cultural resource.

This paper examined sets of pathological lesions which may be linked to both use and biological sex, concentrating on identifying females gender assigned to a primary use as breeding animals. Two specific areas of pathological phenomena were examined: dental anomalies, specifically overgrowths which might be linked with equine dental care practices, and evidence of long-term lameness likely to render the horse unfit for riding or draught purposes. It is suggested here that poor dental care and/or chronic disability are more likely in female horses, gender-assigned to production use in broodmare herds kept in pasture or heath contexts. Historic evidence for early Britain and Northwestern Europe suggest cultural perceptions of gender roles designated male horses (probably intact stallions) as most appropriate for riding, especially within elite and military contexts, while female horses were deemed appropriate primarily for breeding purposes. Other western European cultures may have followed similar culturally determined gender assignments regarding horse use, but further research is necessary to explore gender-assigned horse use. Patterning in pathological lesions, coupled with cultural information, may be used to suggest the likely presence of male or female horses and transport/working horses versus breeding populations in archaeological assemblages.

Present-day evidence suggests pasture/range kept broodmares may be given less regular dental/medical care than use-horses. While irregular dental wear might cause problems with the bit or irritation which could affect the behaviour of use-horses, it was likely not considered a significant issue with minimally handled breeding stock. Significant chronic lameness also would not necessarily inhibit breeding functions and could be neglected in broodmares. The same disability would not be tolerated in most riding or draught horses; those were more likely to be culled before the expression of grave pathological conditions. The author examined a modern horse culled for persistent patellar dislocation lasting some months, and there were no pathological changes evident in the skeleton. This deformation in working male horses would probably have resulted in the horse being culled before the development of massive bony changes.

Attempting to associate activity with osteological symptoms in the skeleton has a long and controversial history both regarding domestic animals and humans. It is often impossible to explain particular skeletal changes with any one particular activity. However, the types of pathological lesions discussed here are interpreted to reflect different levels of human care likely provided to horses with broad use designations (breeding herd vs. working animal) based on culturally determined gender differences between mares and stallions/geldings, rather than specific activities such as pulling vehicles or carrying loads.

The discrete use of DNA sexing to confirm the few osteologically identified females and others identified using the types of pathological lesions discussed here could confirm

whether this suite of osteological changes may be applied to new and re-analysed of horse assemblages. While horse remains are typically infrequent at settlement sites, their cultural importance and wide occurrence in ritual deposits can provide important cultural insights. Palaeopathological methods offer new means of gathering demographic and husbandry information on horses and their roles played in human societies. Hopefully this paper will encourage research into the gendered use of horses through elucidating relationships between the animals' sex and certain pathological phenomena.

Note

1 Sisson and Grossman (1966) The Anatomy of Domestic Animals (4th edn), appears to be an incorrect reference, appearing only in Wilson *et al*. 1982, Bendrey *et al*. 2010, and in the text only of Bulatović *et al*. 2014. The 1975 (5th edn) of Sisson and Grossman's The Anatomy of the Domestic Animals (Getty *et al*. 1975) gives the previous editions as: 1910, 1914, 1938, and 1953. Bulatović *et al*. 2014 also incorrectly cite Johnstone 2004 for May 1985's stature estimation method.

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11. Pelvic Fracture in Horse: A Late Medieval Case from Karcag–Orgondaszentmiklós, Eastern Hungary

Kyra Lyublyanovics

Animal disease has been potentially damaging for society due to the hindrance of agricultural production (working animals) and the loss of meat supply and trading goods (Swabe 1999, 48). Curing a sick or injured animal is always a conscious decision that requires investment and thus reveals either the value put on an animal or the necessities of saving it. In some cases, when the injury is severe and the cure would be too laborious and expensive, animals can be killed and their carcass used for consumption; however, there are instances when individuals in very bad condition are also cared for due to their symbolic value or the owner's emotional attachment to them. Among livestock, horses tend to be in a privileged position from this point of view owing to their high practical value and culturally determined appreciation. In this study, a grave case of pelvic fracture in horse is presented within the context of medieval animal exploitation in Hungary. Cuman pastoralists of Eurasian origins, who settled in the Great Hungarian plain in the late Middle Ages, seem to have placed special value on horses. They had the expertise to cure a grave injury but horses also played an important role in their diet. This may have increased the chances of the archaeological recovery of this special find, brought to light from food refuse.

11.1 Introduction

The practice of taking care of sick or injured individuals in one way or another is probably as old as animal husbandry itself. In the broadest sense of the word, veterinary management of a livestock includes all practices which impact – or are perceived to impact – upon the condition and well-being of the animals. At the broadest level, this incorporates not only direct treatment, but all conscious actions of feeding, watering, pasturing, the manipulation of reproduction, herd management, housing and supervision of the livestock, sanitation, and measures of disease prevention (McCorkle 1986, 131).

Veterinary intervention in the present sense is usually impossible to directly detect in archaeozoological assemblages (*e.g.* if it involved feeding herbs, bloodletting, or simply quarantining a sick animal). Definitions of sickness also varied in the past: ethnoveterinary studies reveal that even emotional reactions and mental states observed in animals may be perceived as illness and treated as such (Hirschkind 2000, 297). Cases

of trauma must have been far less ambiguous in the case under discussion here, a grave but healed pelvic fracture in horse from 14th–16th-century Hungary.

Fractures of the pelvis are usually traumatic in origin and are mostly associated with accidents such as falling and slipping (Baxter 2011, 389). Such finds are extremely rare in the archaeological record, as dislocated fractures of the pelvis are difficult to heal even in the modern veterinary praxis: euthanasia is recommended in case of heavily dislocated and comminuted pelvic fractures. Milder cases are treated if some special value is attached to the horse, *e.g.* it is considered for breeding purposes.

11.2 Provenance

The village of Orgondaszentmiklós, abandoned in the late 16th century, was located in the outskirts of Karcag town, some 3 km north its centre, in the area of present-day Berekfürdő (47° 23′ N, 20° 50′ E) in the Great Hungarian Plain (Figure 11.1). The settlement first appears in the textual record in a 1521 *perambulation* (a document determining the bounds of a legal area). Here, however, nothing is said about the settlement itself, only its name is mentioned (Gyárfás 1870–1885, vol. 3, 752). Archaeological excavations at the site took place between 1971–1973, directed by László Selmeczi of the Damjanich Múzeum in Szolnok.

A relatively large number of animal remains – 1174 identifiable specimens (NISP) – were collected at this site. Given the archaeological methodology of the 1970s, techniques of fine recovery (sieving, flotation) were not used, bones were collected by hand. Approximately 28% of the remains originated from cattle, 14% from horse and caprines each, and 12% from pig. Bones of dogs, poultry and game were also found in small numbers. The species composition is not exceptional; what makes it unusual in a late medieval Hungarian context is the remarkably high ratio of horse bones which actually outnumber that of pigs. Even if horse bone fragments are not taken as evidence for horse consumption at most late medieval settlements, this is not the case here.

Unambiguous butchering marks on bones that represent high quality meat leave no doubt that horses were eaten. The question of the special treatment of horses is raised in connection with a pelvic bone that shows signs of a dislocated fracture, an injury that could not have been healed without human intervention. This individual was definitely cared for, and such a find is quite unique in the Hungarian record.

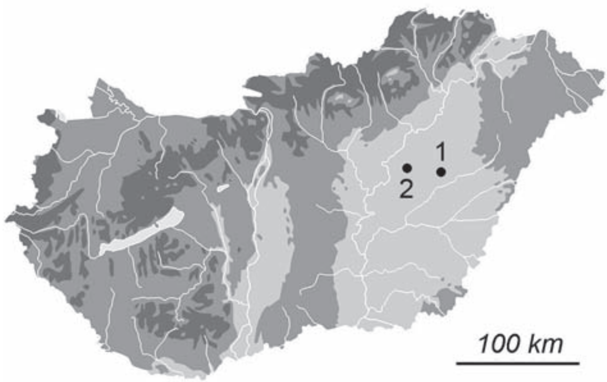

Figure 11.1. The location of Karcag–Orgondaszentmiklós (1) and Tiszagyenda–Morotva-part (2) in the Great Hungarian Plain.

11.3 The pathological specimen: Diagnosis and possible therapy

The horse pelvis fragment under discussion here was recovered from a refuse pit. It shows signs of a healed fracture and displacement, which definitely speaks for human intervention. The left iliac shaft broke into two in a *c*. 10 cm distance from the acetabulum. The ilium was shortened by sliding in a caudal direction, onto the *spina ischiadica*, and changed the normal angle of the ilium, while newly formed exostoses contributed to a further distortion (Figure 11.2). Judging by the fully fused acetabulum, this bone evidently originates from an adult individual; as the find was only a fragment of the whole pelvis and its shape is distorted by the pathological lesion, it was impossible to say whether it came from a mare or a stallion.

The large size of the pelvis, a composite of three pairs of bones, and its complex shape with projecting angles render it especially liable to fracturing. In present-day clinical practice pelvis fracture (*fractura ossis coxae*) is the most common form of bone fractures in all domestic species (Tamás 1987, 331). The prognosis is to be cautious in all cases, but is determined largely by the anatomical location of the injury. It also depends heavily on the degree of dislocation, as the displacement itself can be the root of various problems, such as deformation of the contralateral limb, muscle wasting as a consequence of pain, coxofemoral arthritis, or the compromise of the birth canal in mares (Auer and Stick 2012, 1449–1451); in adult individuals, if the ilium is involved, laceration of the iliac arteries may contribute to acute death (Baxter 2011, 389; Driver and Pilsworth 2009, 139). This evidently was not the case with the Orgondaszentmiklós horse.

Two major groups of pelvic fracture may be distinguished: those of peripheral position and those that compromise the static integrity of the pelvic ring (Hantak and Horváth 1982, 203). Even among the latter, chances of healing are better in the case of iliac wing (*ala ossis ilii*) or symphysis fractures (Wintzer 1997). However, if the acetabulum is involved, chronic lameness is likely to persist as there is only a remote prospect of a reunion between the broken pieces in the hip joint. This renders a working animal useless, since the hind quarter provides dynamic propulsion for upward and forward movements of the mammalian body (Bartosiewicz 2008, 157), often at considerable speed in horses.

According to Axe (1905) the body or the neck of the ilium (*corpus ossis ilii*) may break relatively infrequently. In his classification system, the lesion observed on the Orgondaszentmiklós specimen would correspond to the "transverse fracture of the Os Pubis" (named erroneously but depicted correctly: Axe 1905, Fig. 345c). This is a strong and relatively deeply seated part of the pelvis. One may assume therefore that the bone broke under major impact and became dislocated as muscles and ligaments in the area became contracted in the dysfunctional limb. Components of this situation are shown in Figure 11.3.

The find itself does not reveal the method of treatment, only the end result: complete healing. It is, however, telling that time and effort (possibly even financial) were invested into healing the animal instead of simply slaughtering it, even though horse meat must have been consumed at the site on an everyday basis. This might signify an attitude that reflects the overall value attached to the species. In many cultures, the concept of

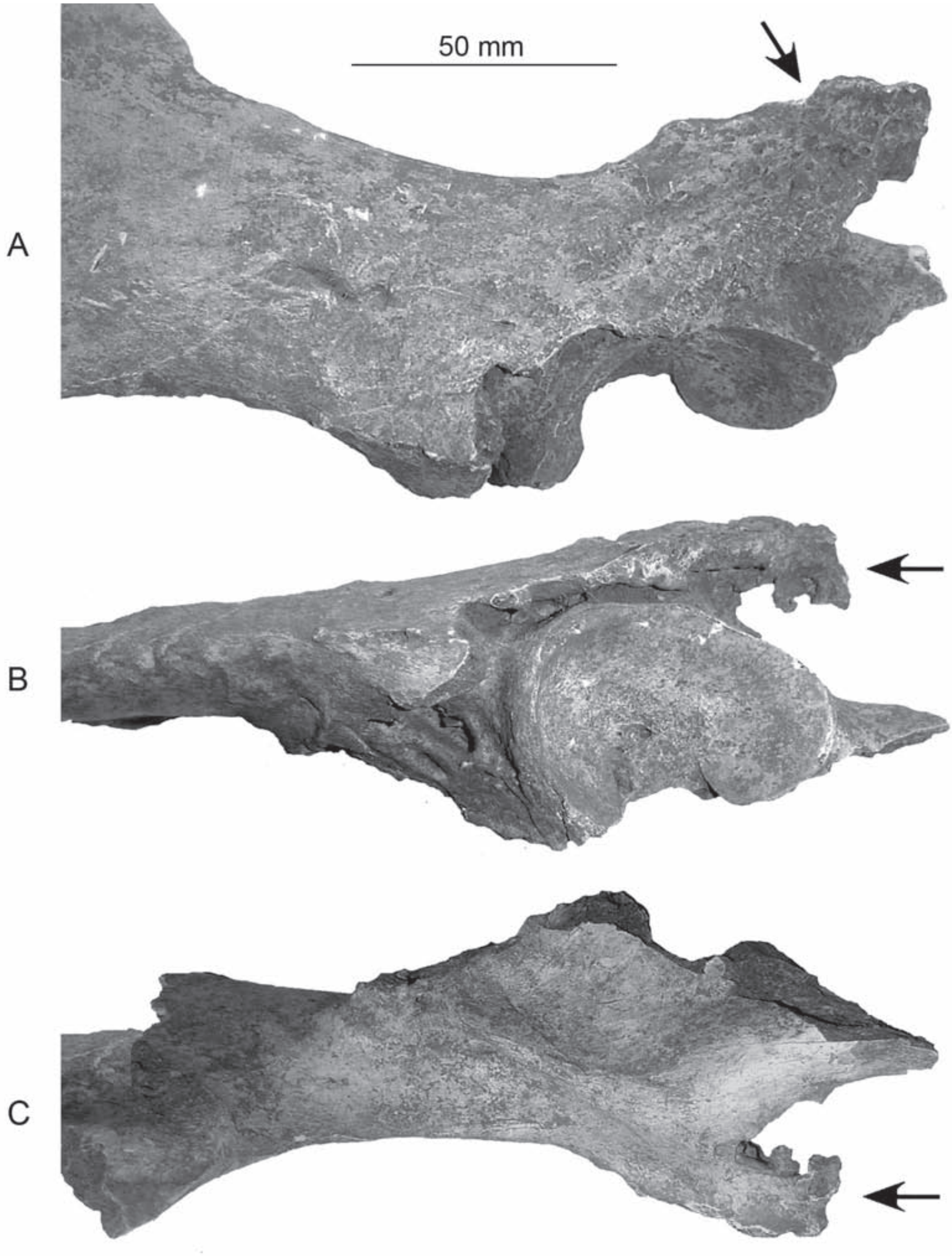

Figure 11.2. Healed pelvis fracture in the 14th–16th century-horse from Karcag–Orgondaszentmiklós showing heavy callus formation around the left acetabulum. A large exostotic protuberance resulting from the dislocation is marked by arrows. Lateral (A), ventral (B) and dorsal (C) aspects.

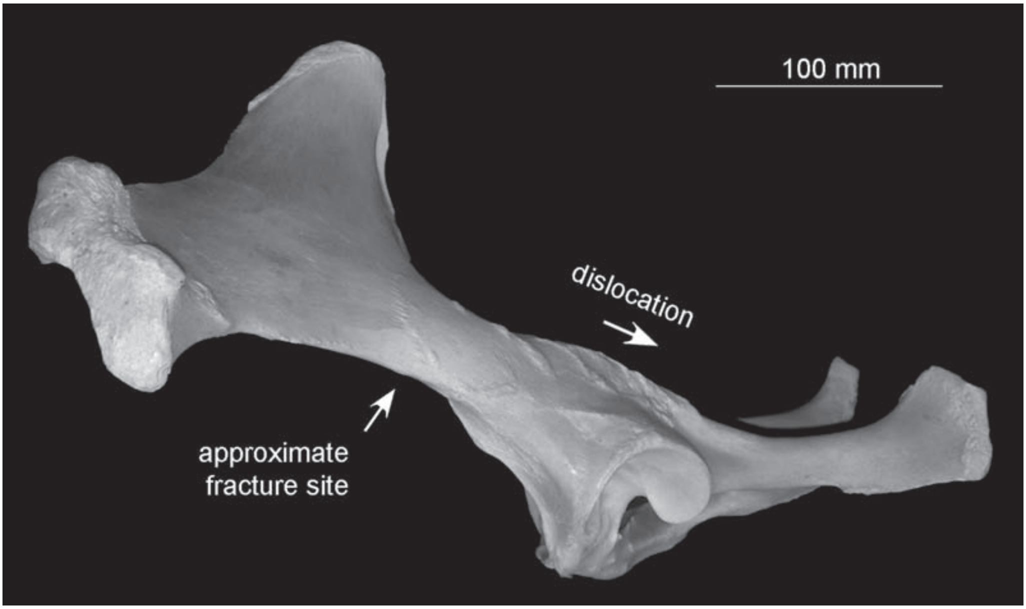

Figure 11.3. Features of the trauma shown on an intact left horse pelvis.

disease has been applied more-or-less the same way to animals and people, and healers who treat humans often treat animals, too. Supernaturalistic therapies of animals might also serve important social and ideological functions (McCorkle and Mathias-Mundy 1992, 59 and 72). It must be kept in mind, however, that all we can reconstruct from the physical evidence of excavated animal remains and the usually scarce textual data is only a small fraction of past animal curing practices.

Overall, the prognosis *quo ad vitam* can vary depending on the localisation and prospective use of the horse. Prognosis *ad functionem* tends to range from careful to bad. The broken pelvis does not lend itself to mechanical restraint usually employed in dealing with fractured extremity bones. Usually, owing to the very imperfect control which can be exercised over the movements of a horse, such injuries are usually treated conservatively (even though iliac shaft fractures can be repaired surgically by internal fixation in case of foals); a stall rest of at least three to four months is required in case of an adult individual (Auer and Stick 2012, 1449).

Promoting bone reparation is restricted to the device of slinging and maintaining the horse's upright posture as accurately as possible, thereby avoiding strain involved in lying down and rising again. This method is shown on a miniature in the 14th-century veterinary treatise of John Alvares de Salamiellas and in the 13th-century Italian book on equine medicine by Jordanus Ruffus (von den Driesch 1989, 122). This old method of support and immobilisation can be effective; indeed, it is used even today as part of the conservative therapy (Auer and Stick 2012, 1047). Although relatively simple, this method required labour and keen attention on the owners' part, and probably a continuous supervision of the injured animal.

11.4 Discussion

11.4.1 Parallels in the region

As mentioned previously, given the complexities of therapy, healed pelvic fractures are rarely identified in archaeological assemblages. The relative scarcity of horse bones among food remains also reduces the chances of recovery. It is perhaps not an accident that the specimen presented here comes from a site where horse remains contributed 14% to the settlement's material.

A similar, although not severely deformed pelvic bone of a horse was found at Tiszagyenda–Morotva-part in a pit dated probably to the 16th century. The site itself is located to only 35 km west of contemporaneous Orgondaszentmiklós. The ischium of the left pelvis above the acatebulum as well as the pubis around the *eminentia iliopubica* are thickened, and there is a build-up of spongy new bone on the *spina ischiadica*. This lesion resembles a minimally displaced acetabular fracture, although the acetabulum itself is not affected. This case seems to have been a greenstick fracture suffered at a young age. This bone also came to light from a refuse pit at a settlement where horse remains contributed 20% to the large assemblage (NISP=4823: cattle 34%, horse 20%, caprines 14%, pig 12%).

Another, earlier example in the region is known from Grave 669 at the Avar period (7th–8th-century) cemetery of Holiare, Slovakia (Ambros and Müller 1980, 181, Tafel XXIX.4). The complete horse skeleton belonged to a 14–15-year-old stallion. This, however, is a non-healed fracture of both the left pubic and ischiadic bones near the cranial third of the *foramen obturatum*. While the acetabulum remained intact, the stubs of both bones show new bone formation indicating that the animal survived the accident. In terms of the statistical probability of manifestation in archaeological assemblages it is remarkable how rarely pelvic fractures have been reported from the numerous Avar period equestrian burials (*cf*. Cross Fig. 10.4, this volume).

11.4.2 Relation to horse meat consumption

It is an interesting question how the pathologically altered pelvis fragment actually ended up in the kitchen refuse. There is no sign of butchering or deliberate cracking on the bone. Nevertheless, it was found detached from the adjoining skeletal elements, which means that the carcass was disarticulated, either for consumption or for other purposes. Another find in this archaeological feature which might come from the same individual, further complicates the picture. This is a right calcaneus exhibiting dense exostoses on the *sustentaculum calcanei* and strong chopping marks on the cranial side of the tuber. Even though it is impossible to say with absolute certainty if this bone fragment belongs to the same individual, its arthropathic lesion may well be the result of the distortion of the contralateral limb, a frequent complication of dislocated pelvis fracture. If it is the case and the animal in question was eventually slaughtered and consumed, there is an interesting contradiction between the efforts made to heal the animal and its eventual slaughter.

Figure 11.4 shows the dietary contribution of horse bones to NISP relative to pig remains at rural settlements during the 11th–13th-century period of the Árpád Dynasty,

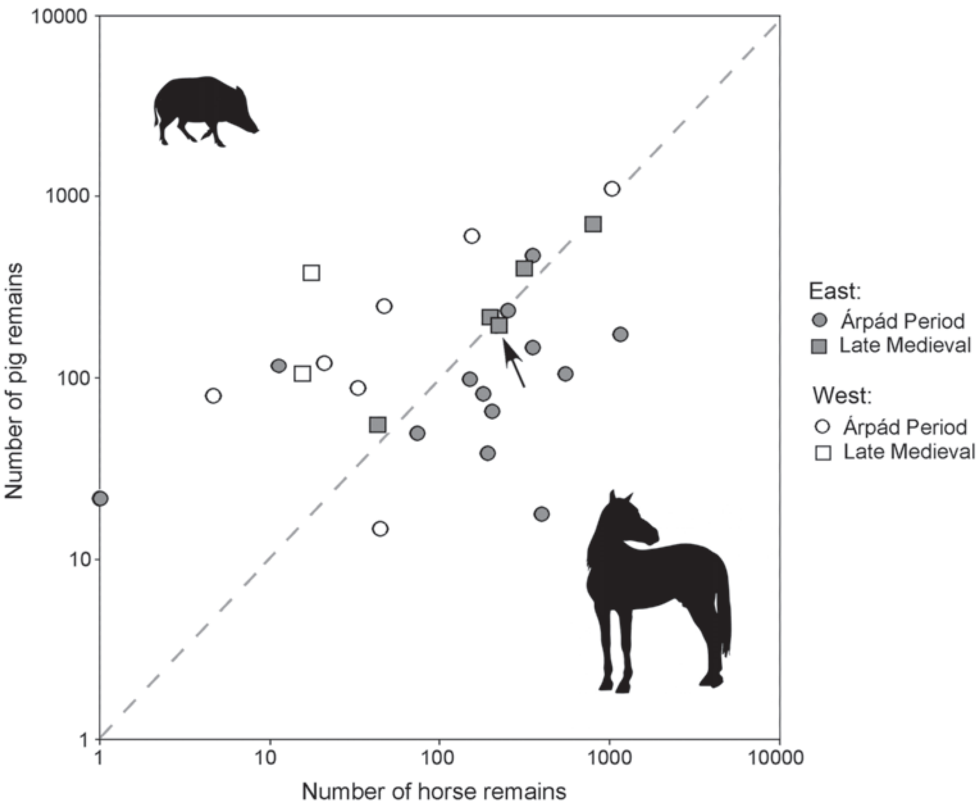

Figure 11.4. Differences between medieval rural settlements in the numbers of horse and pig remains (Bartosiewicz 2018).

especially in Eastern Hungary. This is traditionally explained by the survival of Eurasian mobile pastoral traditions among Hungarians who conquered the Carpathian Basin during the 9th century (Bartosiewicz 2003, 118–119).

In late medieval Hungary (14th–16th century) the extreme dominance of horse remains over those of pig disappears. Contemporaneous settlements in the hilly western section of the country reveal even fewer horse bones. The numbers of horse remains, representing a "steppe" tradition, still rival those of pig at all sites in eastern Hungary. Karcag–Orgondaszentmiklós falls on the diagonal line indicating nearly equal numbers of bones from both species.

11.4.3 Historical context

Eastern Hungary was exposed to several waves of immigration by the Cumans, a Turkic people of Central Asian origin. Fleeing military conflict with the expanding Mongol empire, Cumans sought asylum in Hungary in 1239, entering the kingdom in a large but diverse group. Many were settled in the flat, central section of the Hungarian Plain. This

was a beginning of a long and politically complex, often hectic process of integrating a Eurasian pastoral people into the Christian state of Hungary (Lyublyanovics 2015, 29). Historical accounts of the Cumans often mention the special role horses played in their rituals. William of Rubruck describes 13th-century horse sacrifices connected to burials and the consumption of horses on burial feasts among the Mongols (Rubruck 1990, Chapter 10). In Hungary, these customs were apparently kept even in some cases when the deceased was baptised (Horváth 2001, 126). It is worth to mention here that Cumans served as mercenaries in the Hungarian army well into the 14th century, mostly as mounted archers.

Regular horse meat consumption as well as special efforts in properly tending an injured horse thus fit the cultural tradition of the Cuman population settled in Eastern Hungary.

11.5 Conclusions

The motivation behind veterinary treatment is manifold, and depends on complex factors such as the economic situation of a given family, the size and overall livestock morbidity, the species composition of herds, as well as the cultural, religious, or prestige value placed on a species. It is also influenced by the age and sex of the individual and its emotional significance to the owner. Veterinary treatment is therefore culturally determined and reflects not only the practices known by and available to a given community, but also their preferences and economic strategies.

Different species are associated with different economic and cultural importance and are handled accordingly. Horses occupy a special position among livestock owing to their high practical value, low reproduction rate and culturally determined appreciation. They were of special cultural importance to medieval pastoral communities of Eurasian extraction, settled in the Great Hungarian Plain.

The occurrence of the rare healed horse pelvic fracture presented in this paper results from the key role these animals played at the time: first and foremost, people invested time and effort in curing a grave injury in this animal. In the meantime, the quantities of horse remains encountered in the food refuse from Orgondaszentmiklós and Tiszagyenda (also indicative of a strong cultural preference) increased the statistical probability of recovering such special finds.

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12. Taphonomy and Disease Prevalence in Animal Palaeopathology: The Proverbial "Veterinary Horse"

László Bartosiewicz

In Hungary, information on the palaeopathology of horses varies diachronically reflecting different cultural attitudes. Although ancient human behaviour is an important topic of study, it creates noise in appraising the prevalence of animal diseases in the distant past. Lesions found in four types of deposits are compared: 3–8th-century Migration period horse burials have yielded complete skeletons. These offer multiple, high resolution data, unrivalled by the remains of ordinary meat purpose domesticates found in the form of disarticulated bones. Although the so-called "horse hide" burials of the 9th-century period of the Hungarian Conquest are fewer and contain only skulls and distally located bones of the feet, the age, sex and stature can still be estimated and used in appraising the morbidity animals. The eastern pastoral tradition of eating horses survived in Hungary during the 11th–13th centuries, in spite of increasing sedentism and the adoption of Western Christianity. However, horse bones recovered from settlement refuse offer only a random representation of pathological phenomena. Following the 13th-century Mongol Tartar incursion the consumption of horse meat was largely abandoned. Late medieval evidence usually originates from mounts or draught horses skinned and disposed of in marginal areas. In addition to such differences in deposition, the selective preservation of resistant skeletal parts also influences surviving pathological information.

12.1 Introduction: Emphasis on horse

Opening almost any modern atlas on veterinary anatomy (*e.g.* Ellenberger and Baum 1912; Kovács 1958; Fehér 1980; Barone 1995), horses are of paradigmatic importance. Other species, even if discussed, are usually treated after and with reference to this emblematic animal. In modern veterinary science bone disease is of major interest only in curing horses (and pets), non-meat purpose animals of high emotional and market value expressed in longevity. In archaeological deposits, the relatively few horse remains are often found as articulated skeletons, typically of fully grown individuals.

In the western world, relevant texts survive from late antiquity. Works by Pelagonius, "Chiron" and Vegetius have been among the most influential. It is noteworthy, however, that they had focussed on horses. Two of them originate in the mid-4th century AD: *Ars veterinaria* by Pelagonius is a hippiatric work influenced by the Greek equine

veterinarian Apsyrtus in the service of the Roman Emperor Constantine I (306–337). *Mulomedicina Chironis* is treating horses, asses and mules although health care for domestic ruminants and pig are also included in the last two of ten volumes. Both books became the main sources for *Mulomedicina*, written by Vegetius in the late 4th/ early 5th century AD. The significance of the latter work was that it discussed horse husbandry by the Huns and other non-Roman "Barbarians", who had no written histories of their own (Mezzabotta 2000, 63). Similarly to these classical Latin sources, *Hippiatrica* written in the Byzantium during the 10th century AD, focussed on treating strategically important horses.

Veterinary literature in Hungarian began in the late 18th century with the translation of *Ein New Buch von bewehrter Ross Artzeneyen* by Martin Böhme, published in Berlin in

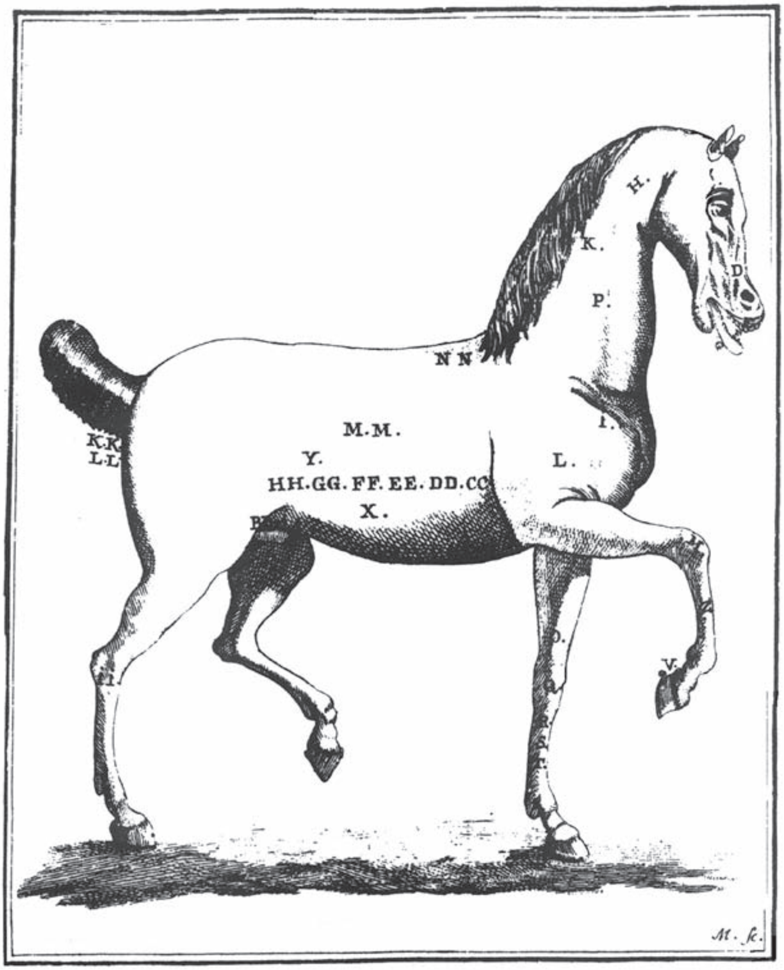

Figure 12.1. Illustration from the 1792 Hungarian translation of the veterinary book by Martin Böhme.

1616 (Tseh 1797: even the author's name "Czech" was translated; Figure 12.1). When the original text was written, Hungary had still been under Ottoman Turkish occupation, but healing military horses became a priority once the country became part of the Hapsburg Empire. The first veterinary school in Pest was established by Emperor Joseph II in 1782. Curing horses had dominated veterinary science until cavalry began losing importance during the Crimean War (1853–1856) that saw the introduction of trench warfare (Gál 2009, 85).

The special role of horses often surfaces in the archaeological record. It is not only horse tackle – often executed in valuable materials showing artistic skill – and iconographic evidence that illustrate the significance of horses. Special forms of deposition offer insight into the relationships between horses and humans that have varied broadly between cultures.

12.2 The problem

Assessing disease prevalence in archaeozoology would be of utmost importance. Pathological specimens should no longer belong to Renaissance style "cabinets of curiosities", their broader context also needs to be understood. The standardised recording of symptoms and consistently quantified rates of prevalence would help producing meaningful diachronic as well as geographical syntheses (O'Connor 2003, 195).

In clinical epidemiology, however, prevalence is defined as the total number of cases of the disease in the (living) population at a given time divided by the number of individuals in that population. This poses a challenge even in the analysis of human remains in archaeology, although usually skeletons of complete individuals are recovered. Ordinary meat-purpose livestock, however, were seldom accorded proper burials. Their bodies were inevitably disarticulated and butchered limiting the "prevalence" of pathological lesions to isolated bone specimens lacking biological context. Given the low chronological resolution of absolute dating and the controversy of estimating the minimum numbers of individuals (MNI; *e.g.* Gautier 1984) archaeozoologists have usually resorted to studying percentages of pathologically modified bones relative to all identifiable specimens (NISP) as a rough proxy to prevalence (*e.g.* Siegel 1976). The underlying assumption is that relying on large series of data the law of large numbers (LLN) will be asymptotically approaching clinical prevalence. While theoretical details of estimating disease prevalence need to be worked out in animal palaeopathology, taphonomic implications of cultural variability in horse deposition offer several examples why a robust but straightforward statistical approach is difficult to pursue. At this stage, no all-inclusive model can be built onto the examples reviewed in this paper. Rather an inductive approach is presented illustrating the various levels of pathological information observed in different types of horse deposits.

In Hungary, quantities of horse remains began occurring at Early Bronze Age sites, while complete skeletons are known from Iron Age Scythian wagon burials (Bökönyi 1974). Such cases, however, are rare with no pathological lesions reported. Diverse types of deposition became most typical by the time of Roman occupation during the 1st century AD, the Migration period and the Middle Ages when horse remains were represented in at least five distinct forms of decreasing skeletal integrity:

1. Skeletons in specific animal burials (Roman and Migration period Germanic peoples) or as companion animals in human graves (Avars, Cumanians),
2. Skulls and distally located limb bones (auto- and metapodium) were presumably left in "hides" added to the grave furniture (Early Avars, Conquering Hungarians),
3. Horse skulls on display (medieval Hungarians),
4. Dry limb bones associated with hide processing (medieval and post-medieval sites),
5. Food refuse (Roman period Sarmatians, medieval Hungarians of the 10th–13th period of the Árpád Dynasty, Cumanians).

These five forms of deposition may be described as associated bone groups (ABG) expressing the degree to which a horse carcass was dismembered and processed for food or raw materials (Hill 1996; Morris 2011). The interpretation of an ABG depends on the archaeological context, influenced by the assumptions concerning find circumstances. Greater skeletal integrity is usually seen as reflecting ritual treatment, but precise interpretation frequently remains impossible unless aided by documentary evidence or viable ethnographic parallels. Figure 12.2 shows the chronological positions of these equestrian groups of Germanic and Inner Asiatic ancestry in the Carpathian Basin. Evidently, their different attitudes to invariably important horses acted as biostratinomic filters between the animals' death and deposition, determining the availability of body parts for palaeopathological study.

The five types of ABGs in the list yield pathological information that makes comparisons between archaeological periods difficult. Moreover, examples from 14 sites (Figure 12.3) discussed in this study originate from various parts of the Carpathian Basin representing an uneven admixture of archaeological periods. A broader view on horse morbidity in antiquity was outlined using an additional set of 22 assemblages published in the international literature summarised in the Appendix.

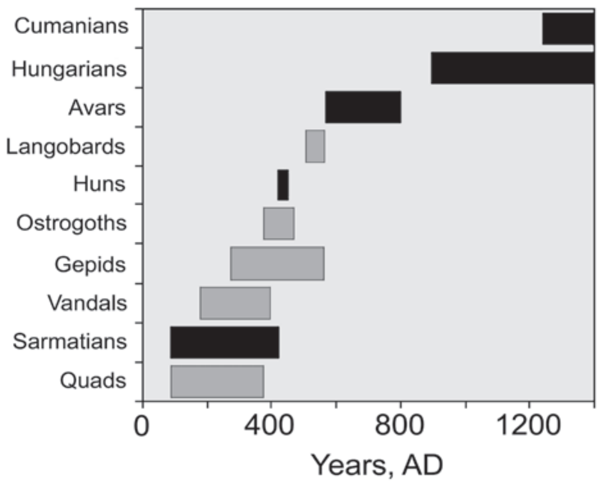

Figure 12.2. The documented presence of major equestrian groups of Asiatic (black bars) and Germanic (grey bars) origins in the Carpathian Basin.

12.3 Differential representation

Skeletons from horse burials are comparable to articulated human remains offering concise information on the age, sex and possible social status of the interred animal as well as the pathological lesions accumulated during the animals' life. Hundreds of proto-historic horses were interred in Roman period and early medieval graves throughout Central and Northern Europe

(*e.g*. Ambros and Müller 1980; Müller 1966, 1985; Müller and Ambros 1994; Reichstein 1991; Daugnora and Thomas 2005, Gerken 2009). The prevalence of pathological lesions identified on individual horse skeletons is closest to the idea of clinical prevalence, as long as a fair number of healthy horse skeletons are also available for study. The frequency distributions of pathological lesions in complete skeletons are comparable between a set of 232 inhumation graves (Regöly-Mérei 1962) and 131 6th–8th-century Avar period burials of complete horses (Bartosiewicz 2002, 35) when all types of pathological phenomena are counted individually. However, even when articulated animal skeletons are available, it must be remembered that the osteological symptoms related to age as well as various diseases, are cumulative (Levine 1999). Longevity itself creates a predisposition to deteriorating health and increasing statistical probability of trauma. The *post mortem* state of the skeleton reflects the amalgamation of numerous processes that cannot always be separated from each other (Prilloff 1991, 61).

The next type of deposition tends to be related to human burials and has been traditionally interpreted as the remains of horse hides with the skull and dry limb bones included (Vörös 2000, 398). These are diagnostic parts of the skeleton indicative of age,

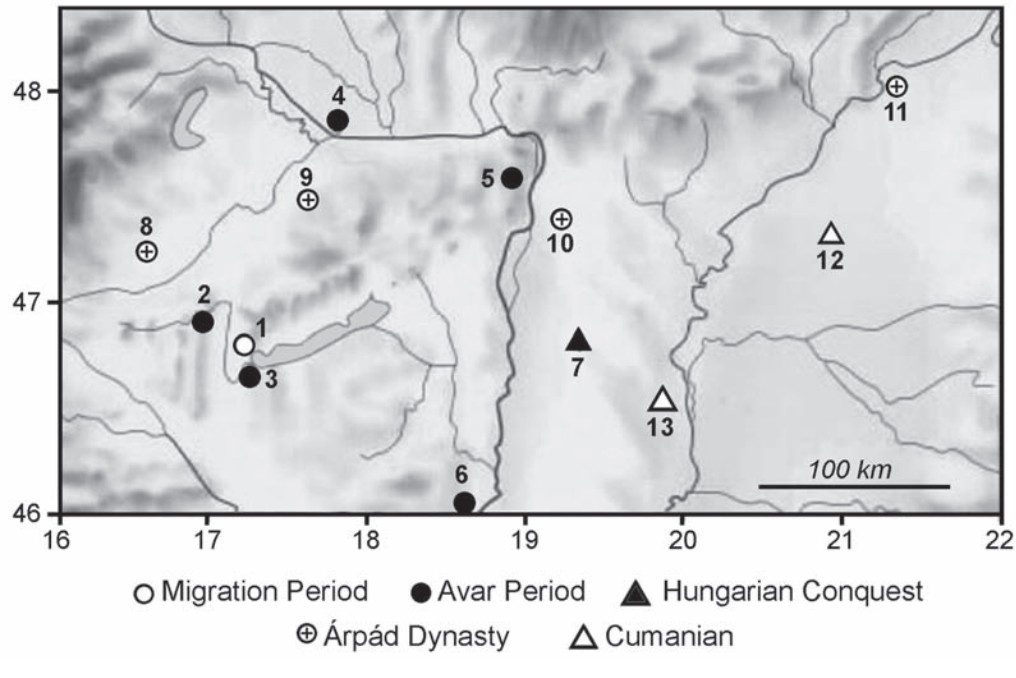

Figure 12.3. Archaeological sites in the Carpathian Basin mentioned in the text. Legend: 1 Keszthely, 4th c. *Migration Period; 2 Pókaszepetk, 7th* c. *Avar Period; 3 Vörs, 8th–9th* c. *Avar Period; 4 Holiare (Slovakia), 7th–8th* c. *Avar Period; 5 Solymár, late 7th* c. *Avar Period; 6 Kölked A, 7th* c. *Avar Period; 7 Izsák, 10th* c. *Hungarian Conquest Period; 8 Szombathely, 10th–11th* c. *Árpád Dynasty; 9 Kajárpéc, 10th–12th* c. *Árpád Dynasty; 10 Gyál, 10th–12th* c. *Árpád Dynasty; 11 Tiszalök, 10th–12th* c. *Árpád Dynasty; 12 Karcag, 14th–16th* c. *Cumanian; 13 Csengele, mid-13th* c. *Cumanian.*

sex and stature. Moreover, the study of 280 complete medieval skeletons by Daugnora and Thomas (2005, 73) has shown that pathological changes were concentrated in the head, vertebrae and distal extremities. "Hide burials" therefore offer valuable data for the reconstruction of individuals they do not represent, however, the trunk and proximal extremity segments.

The remaining types of deposition are more typical of settlements and represent further steps in the selectivity of skeletal parts. They include finds of isolated horse skulls, usually still within the realm of sacral behaviour, as horse heads have been popular objects for apotropaic displays (Bökönyi 1978) and other forms of poorly understood rituals.

At the other extreme, due to the diachronically declining contribution of horse meat to diets across medieval Europe (Van Wijngaarden-Bakker and Krauwer 1979, 40), historically later, especially urban deposits tend to contain distal extremity bones either as probable by-products of tanning or in manufactured forms such as skates. In these types of deposition, the further separation of diagnostic body parts by sacral and technological uses compromises the biological integrity of the horse skeleton in estimates of disease prevalence.

In terms of the taphonomic loss of palaeopathological information the worst are horse bones found among mundane food refuse, such as the animal bones left behind by Roman period Sarmatians in eastern Hungary or early medieval Hungarians (Bartosiewicz 2003). Horse flesh consumption became an ideological issue when St. Boniface converted Germanic tribes to Christianity in the mid-8th century. In 732, when Pope Gregory III extended the same support to him which had been afforded by Gregory II, the pope called consuming horse flesh a "filthy and abominable custom", to be banned (Tangl 1955, 26). This statement has sometimes been over-interpreted as a religious taboo against eating horse meat. The custom, however, evidently survived for some three centuries in the Christian Kingdom of Hungary established in 1000. It was common until the mid-13th century as long as a strong steppe tradition prevailed among sedentary Hungarians in the Carpathian Basin. Subsequently, Cumanians immigrating from the East reinforced the declining trend of horse meat consumption (*cf*. Lyublyanovics, this volume). In other words, sporadic evidence of horse pathology is available on isolated horse bones in settlement debris. This is the type of deposition which produces quasi-prevalence rates comparable to those of meticulously disarticulated common livestock such as cattle or pig, regularly exploited for meat.

12.4 A brief review of examples from Hungary

Wherever appropriate, "prevalence" in horse palaeopathology should be seen in light of the previously detailed taphonomic considerations. The five degrees of skeletal integrity are determined during the anthropogenic phase of biostratinomy, *i.e*. the taphonomic history of the animal between death and final deposition.

12.4.1 Head and dentition

While cavernous flat bones of the *calvarium* are prone to fragmentation, skull remains are equally available in horse burials, "hide" deposits and in the form of completely isolated

skulls recovered at settlements. In comparison with other animals our knowledge of cranial pathologies in horse is relatively rich. Among these, evidence of trauma has been most widely discussed in the literature.

In two cases regular, square-shaped multiple perforations were found on the foreheads of isolated horse skulls from 10th–12th-century AD settlements in Hungary (Tiszalök–Rázom: Bökönyi 1974, 294; Kajárpéc–Pokolfadomb: Takács 1993, 229, figs. 15–16). Such serial lesions may be attributed to potentially fatal blows delivered with a pick-like, pointed weapon. It is usually impossible to tell, however, whether this intensive damage was *peri-* or *post-mortem* in origin (Figure 12.4).

Figure 12.4. Multiple skull perforations on a horse from Tiszalök–Rázom, Hungary. Frontal aspect. At least seven square holes are clearly visible on the frontal bone above the orbits. The peri- or post mortem origins of the holes cannot be distinguished.

A depression or pond fracture was discovered on the left forehead of another disarticulated horse skull found among the refuse bone at the 10th–12th-century settlement of Gyál 3/a, Hungary. Unhealed cracks around this lesion indicate that this was a *peri mortem* injury (*Figure 12.5A*). The analogous trauma shown in the same figure (B) illustrates the first attempt to kill a present-day stallion in 1963: this blow caused a depression fracture surrounded by radial cracks. The second blow perforated the frontal bone near the junction between the two *lineae temporales* on the parietal bone. A similar, depression fracture was described in the middle of the forehead of an 8–9-year-old individual from the 7th-century Avar cemetery of Pókaszepetk, Hungary. The blow left a plum-sized depression in the middle of the left frontal bone (Bökönyi and Matolcsi 1994: 212).

Although no exact sample size was published, based on a nearly four decades long post-war clinical record at the University of Veterinary Sciences in Budapest, mandible fractures made up only 4.88% of all fractures in modern horse (Tamás 1987, 44). Mandibular injuries of equids are likewise rare in archaeozoological assemblages. A healed fracture with callus running all along the *angulus mandibulae* was identified on a 13th–14th-century domestic ass at the tell settlement of Takht-i Suleiman (Iranian Azerbaijan; Steber 1986, 93, Taf. 1/Abb. 1/b).

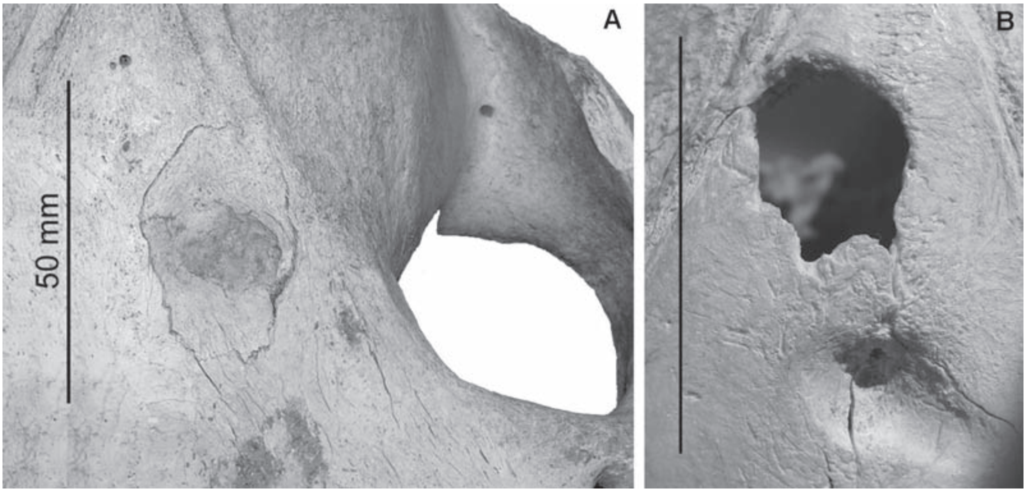

Figure 12.5. Perimortem pond fracture on the forehead of a horse from the 10th–12th-century settlement of Gyál 3/a, Hungary (A). Analogous perimortem pond fracture and lethal perforation on the parietal bone of a present-day stallion (B). Frontal aspects.

A special type of impression resulting from bone remodelling, was detected by István Takács (1996, 401) across both nasal bones of an Avar period horse from the cemetery of Kölked–Feketekapu A, Hungary. This slight deformation more-or-less corresponded to the placement of the nose band. The transversal thinning or thickening of nasal bones was explained by bone remodelling in response to prolonged harnessing. Bökönyi (1968) identified bit wear marks on the orally positioned lower 2nd premolar teeth during the study of Iron Age horse burials at Magdalenska Gora (Slovenia). Since then, several publications by Brown and Anthony (1998), supported by the evidence of scanning electron microscope studies, have discussed the role of bridling in the domestication of horse based on bit wear. In Hungary, macromorphological studies were carried out by Takács (1985) on the premolar teeth of complete Avar period horses buried at the cemeteries of Kölked–Feketekapu A, Solymár and Vörs–Papkert. Wear is usually confined to the first, paraconid cusp of the P_2 tooth. While not a major pathological modification, bit wear occurs in over 90% of frequently bridled modern horses (Brown and Anthony 1998, 331). An extreme case was observed at Kölked–Feketekapu A (Figure 12.6), probably resulting from the bit-biting, the horse regularly "resting" the bit on the pair of P_2 teeth to alleviate pressure on its mouth.

A dental anomaly associated with non-working is also worth mentioning. Sometimes fine wear on the labial edges of incisor teeth may be observed *e.g.* in the AD 670–700 Avar period horse burial from Solymár, Hungary (Takács 1994, 157, grave 20). It may be interpreted as a sign of crib-biting (Tamás 1987, 107, fig. 142). Domestication means that many animals kept in passivity, develop forms of behaviour that would be called neurotic in humans. According to Firouz (1996, 2), six-month-old Turkoman colts in Iran are "staked out on long ropes and from then on are never turned loose. The colt

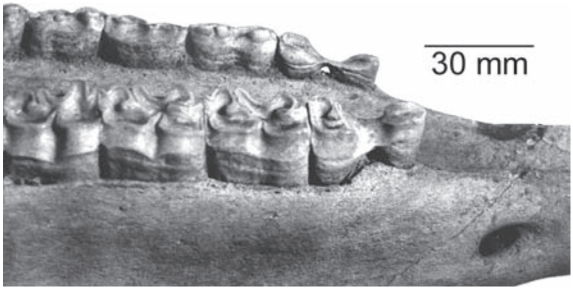

Figure 12.6. Extreme toothwear resulting from bit-biting on the lower P_2 teeth of an Avar Period horse from Kölked–Feketekapu A, Hungary. Linguo-buccal aspect.

is ... immediately bitted and, except when eating, has the reins tied up around his surcingle to prevent nosing on the ground." Although crib-biting is an extremely complex ethological phenomenon, it seems to coincide with this type of wear on the labial edge of horse incisors.

The clinical prevalence of caries varied between 0.5% (n=440 individuals) and 2.5 percent (n=558 individuals) in modern horse. It is noteworthy that when a large series of some 2000 individuals was studied the average of these extremes (1.2%) was obtained (Tamás 1987, 111). All these values, however, fall far behind the 13.6% reported for horses by Colyer (1936).

One of the reasons for the development of this condition in Equids may be *campylognathia*, the distortion of the maxilla relative to the mandible (Tamás 1987, 102, fig. 128). A relevant archaeological example is the "hide deposit" including the skull and dry limb bones discovered in a grave from the mid-10th-century Hungarian Conquest period at the site of Izsák–Balázspuszta, Hungary. In this approximately seven-year-old stallion, a congenital linguobuccal curvature of the entire *calvarium* exposed the occlusal surface of the lower P_2 tooth. Insufficient wear in this area thus resulted in "excess growth" (Matolcsi 1976, 197–199, figs 2–4). Among others, this situation may be the consequence of peri- or postnatal trauma, as was observed on a late medieval horse skull from den Burg, Texel, and the Netherlands. The broken upper P^4 and damaged M^1 teeth of this individual led to the similar overgrowth of the mandibular P_4 tooth (Van Wijngaarden-Bakker and Krauwer 1979, 42, figs 2–3). In contrast to these massive deformations, the wavy wear pattern on the occlusal surface of both the upper and lower cheek tooth rows in the 8–9-year-old Germanic stallion, described as a "shaman horse", from Keszthely, Hungary, seems to have been caused by a slight, inherited *prognathia superior* (Vörös 1999, 122). The same individual, however, also possessed a superfluous lower incisor that grew buccally of the left I_3 tooth (Bökönyi 1974, 292). This phenomenon within the same skeleton indirectly points to the possibly complex hereditary background of the horse which may or may not be related to debilitating ankyloses in its vertebral column to be discussed in the next section.

12.4.2 Postcranial axial skeleton

Vertebrae and ribs can be precisely studied in articulated horse burials, as the exact anatomical position of these serial of bones can be identified. For example, a rare example of greenstick fracture was described by Boessneck and Meyer-Lemppenau (1966, 132, Abb. 2a–b) in a Roman Imperial period skeleton at a Germanic site near Seinstedt, Germany. The right 8th rib of this animal broke but no callus formation

occurred on its ventral side. Fractures with concentric, radiating and stellate appearance are typical for living bone.

In clinical practice, the osseous fusion between vertebrae (*spondylosis ankylopoetica*, SPA) in horses, is conventionally regarded as a combined result of mechanical overburdening and old age (Kardeván 1976, 631). While various stages of this condition are well known (Stecher 1968; Rooney 1997), the fusion of over ten vertebrae, however, is rare: modern veterinary practice prevents the full development of such grave symptoms as animals would be culled on both economic and humane grounds. Due to the diachronically declining contribution of horse bones to archaeozoological assemblages, intervertebral fusions have been occurring rarely by the Middle Ages (Van Wijngaarden-Bakker and Krauwer 1979, 40, figs 4–5). In Central Europe, however, SPA is best known from horse burials dated to the second half of the 1st millennium AD (Müller 1966, 1985; von den Driesch-Karpf 1967; Müller-Wille 1970–1971; Ambros and Müller 1980; Müller and Ambros 1994). Some cases were recorded at earlier Roman provincial sites (Boessneck and Ciliga 1966, 150; Boessneck and Meyer-Lemppenau 1966; von den Driesch 1969; Haimovici 1983), while an Iron Age (5th century BC) individual was reported from Magdalenska Gora in Slovenia (Bökönyi 1968).

It has been widely assumed that these lesions result from repetitive strain injury (RSI) caused by riding. Levine *et al*. (2005, 12) postulated that in Scytho-Siberian horses, this condition spread with the use of a saddle that rests directly on the spinal processes of the thoracic vertebrae. Passage 32 in a 1945 manual on horsemanship from Mongolia (Meserve 1999, 306) advises to "put the saddle forward on the horse with high withers and high chest. Put the saddle back on the horse with hollow withers and a long, narrow chest". Should this have been a practice among ancient equestrian peoples, the thoracic region of the vertebral column may indeed have been exposed to various forms of RSI. The condition is evidently exacerbated by acute trauma. Callus formation was observed on the right side between the 1st and 2nd sacral vertebrae of a 7.5-year-old Arabian type stallion recovered from a mid-13th-century Cumanian grave at Csengele, south-eastern Hungary (Mojzes 2001, 349, fig. 1). The resulting swollen osseous substance has made the exit point of ventral spinal nerves between the two vertebrae asymmetric. A bony bridge between the transversal processes of two lumbar vertebrae on the same side ended mobility between the two bones (Mojzes 2001, 349, fig. 2). In mammals, however, the flexibility of the vertebral column decreases in a cranial to caudal direction anyway (Bartosiewicz 2008a, 157–158) and in horse natural fusions may occur even between the transversal processes of the last lumbar vertebrae. It is therefore interesting that in the horse skeleton found in Grave 2 at the 7th–8th Avar cemetery of Holiare, Slovakia (Ambros and Müller 1980, 73) the transversal process of the first lumbar vertebra was broken and remained in contact with the *corpus vertebrae* only through a synchondrosis. Emphasis on SPA in vertebrae inevitably simplifies the natural continuum between healthy to ankylosed specimens: intervertebral fusions begin with "other", milder, symptoms. Many of these latter occur in another important form of vertebral lesion in horse, the occasional presence of a traumatic fissures crossing the concave caudal articular surface (*fossa vertebrae*) in a mediolateral direction near its ventral third (Müller 1985, Taf. III.5, 7 and Taf. IV.1, 6), also attributable to RSI.

The three Germanic animal burials, including the aforementioned "shaman horse" with 17 fused vertebrae (T_{18}–L_3; Figure 12.7) found at Keszthely, Hungary (Bökönyi 1974, 290–291) have recently been revised by Bartosiewicz and Bartosiewicz (2002). Such extreme cases of SPA in the vertebral column cannot be explained by only riding partly because they would have precluded the use of such animals as mounts. As of today, much as in humans, SPA is incurable in horse (Tamás ed. 1987, 272). A genetic component may be suspected behind extreme cases.

Infections form another important source of SPA in horse. Infiltrating tuberculosis caused by *Mycobacterium* species may lead to excess bone growth that tends to connect articular surfaces (*arthritis tuberculosa pannosa*; Kardeván 1976, 634) sometimes resulting in ankylosis, such as the fusion between three thoracic vertebrae in a 10th–11th-century adult horse from the outskirts of Szombathely, Hungary (Nyerges 2009). This specimen shows extreme fistulation, although TB in the spine tends to be more common in the cervical vertebrae of horses (Fröhner and Zwick 1925, 1090).

In clinical practice, infections caused by *Brucella* species are best known to effect bone in cattle and horse. In cattle, advanced brucellosis may cause chronic arthritis, polyarthritis and may culminate in ankylosis. Brucellosis may also induce granulous bone lesions in vertebrae. Differential diagnosis between these two infectious diseases, however, is hampered by the great intra- and interspecific variability of symptoms in both diseases that may affect the bone tissue in similar ways. Chances of distinguishing between tuberculosis and brucellosis on an osteomorphological basis are somewhat better for animals whose complete skeletons are recovered and where the distributions of various lesions can be compared. Unfortunately, the macroscopic study of carefully recorded proliferative periosteal lesions in the form of newly woven bone

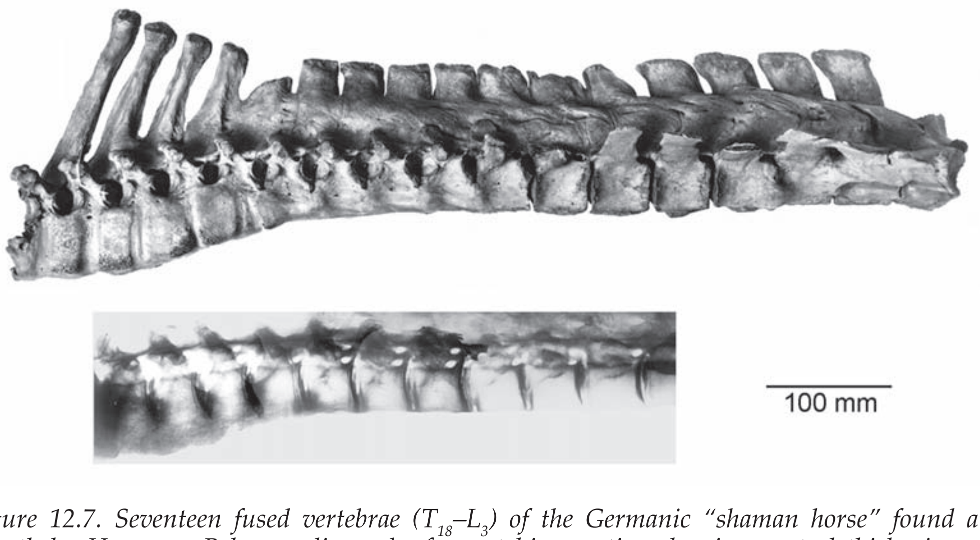

Figure 12.7. Seventeen fused vertebrae (T_{18}–L_3) of the Germanic "shaman horse" found at Keszthely, Hungary. Below: radiograph of a matching section showing ventral thickening of the large articulations in the thoracic (left) and dorsal ankylosis in the lumbar region (right). Left lateral aspect.

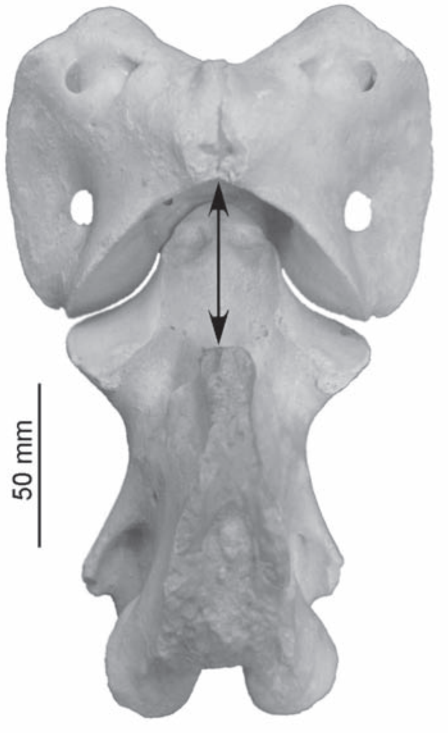

Figure 12.8. The length of the intervertebral opening (arrow) between the first (top) and second cervical vertebrae in horse.

on the vertebrae and ribs of the complete Iron Age horse skeleton from Viables Farm, Basingstoke, England (Bendrey 2008, 23–24), did not permit differential diagnosis due to the similarity of osteomorphological symptoms. The discussion of protohistoric horse vertebrae would be incomplete without mentioning a peculiar form of injury across the cranial articular surface of the epistropheus (*dens epistrophei*) first observed by Hans-Hermann Müller (1985, Taf. II–III). This type of trauma observed on 7th–8th-century horse burials at Ammern, Kapellendorf and Kaltenwestheim–Rinderstall (Germany) as well as Komárno–Hadovce (Slovakia) seems to be related to slaughtering. The fine cut marks on the dorsal surface of the *dens epistrophei* (near the articulation between the 1st and 2nd cervical vertebrae), seem to originate from stabbing that disrupted the spine from a dorsal direction (Müller 1989, 295, Abb. 2). At this point a several centimetres long intervertebral opening exposes the animal's spine (Figure 12.8). A modern day ethnographic parallel to this method was recorded among the Beltir people of the Minusinsk Basin in south-central Siberia where sacrificial horses are stabbed in the nuchal region "between the ears and the nape" (Kralovánszky 1985, 368).

12.4.3 Appendicular skeleton – proximal segments

Known pathological lesions are relatively rare on bones in the shoulder and pelvic girdles of ancient horses. The frequency of healed trauma somewhat increases in a distal direction along the extremity. The special care broken-legged horses require, possibly including prolonged suspension of the body, is supported by medieval iconographic evidence in the 15th-century work by Johan Alvarez de Salamiella (Schwartz 1945; von den Driesch 1989a, fig. 172). Spondylosis deformans was described on the mediodorsal side of the right humerus in the shoulder joint of a 3rd century horse skeleton from the Germanic site of Feddersen Wierde, Germany (Reichstein 1991, Taf. 18/4). Periarticular exostoses were reported around the acetabulum of a disarticulated pelvis fragment from the 4th BC–3rd century AD settlement of Lidar Höyük, Anatolia/Turkey (Kussinger 1988, 98) and from 14th–16th century-Bad Salzulfen, Germany (Schreiber 1989, 228–229, Abb. 1). These lesions may be related

to overworking and longevity of working animals. According to the modern clinical record pelvis fractures occur relatively commonly in large stock (Tamás 1987, 331). The prognosis of this trauma, however, must have been very bad in the past. A disarticulated broken horse pelvis recently recovered from a refuse pit at the 14th–16th-century Cumanian site of Karcag–Orgondaszentmiklós, Hungary (Lyublyanovics 2015, also this volume) is of special interest. This left ilium broke near the acetabulum of the hip joint, and healed completely, retaining a dislocation as the two bone surfaces slid onto each other, although the articular surface itself remained intact. In principle, the animal must have been immobilised for at least several weeks in order to allow the bone to heal, testifying to the special value attached to the horse, whether economic or emotional. Since Cumanian pastoralists consumed horse flesh (at least 14% of the 1625 identifiable bones at the site originated from horse; Lyublyanovics 2015) it is remarkable that this animal was allowed to recover from the accident.

Long bone deformations are similarly rare in the stylo- and zygopodium zones of extremities. Periostitis ossificans and traumatic osteophyta formation were observed on the median side of the distal articular end of the humerus (*trochlea humeri*) from a Roman-period horse skeleton in Künzing-Quintana, Bavaria, Germany (Swegat 1976, 82). Periostitis and flattened exostoses were recorded on the anterior-medial side above the distal epiphysis of the left tibia in a late 5th–late 4th-century BC horse at Pizzica-Pantanello Italy (Bökönyi 2010, 30), while *arthropathia deformans* was noted along the *crista tibiae* at the Germanic settlement of Feddersen Wierde (Reichstein 1991, Taf. 16/1).

12.4.4 Appendicular skeleton – distally located limb bones

This group of bones forms the animal's foot. They are robust, poor in meat as well as marrow. Therefore, their anthropogenic damage tends to be minimal in archaeological deposits facilitating the diagnosis of pathological lesions. Such bones may be included in "hide burials" along with the skull or appear at settlements in tanning refuse.

The most spectacular specimens are rare healed metapodium fractures in horse. Iron Age examples from different parts of Europe include a simple fracture on a metacarpus that healed with a minor dislocation and minor shortening recovered from the Iron Age hill-fort of Stična, Slovenia (Bökönyi 1994, 203, fig. 142). Deviation from the bone's long axis (*dislocatio ad axim*) caused shortening of another horse metacarpus embedded in thick callus found at the Celtic settlement of Manching, Bavaria. This latter case is an example of an infected compound fracture that healed with significant shortening and major deformation (von den Driesch 1989b, 651, fig. 12). Another compound fracture of the left third metacarpal of what was most likely a working mare buried in the human cemetery of 4th–7th century BC Sindos, Greek Macedonia seems to reconfirm that such fractures were managed. The animal survived for over 3–4 years, the bone showing a considerable post-treatment angle as well as the physiological dissolution of the bone mineral content (Antikas 2008, 26, fig. 5).

Chances of healing are slightly better in the pelvic extremity. While the hind leg plays a more dynamic role in locomotion, its static loading is smaller than that of the front limb that carries approximately two thirds of the static body weight in horse. A well-healed

metatarsal fracture was found at the Iron Age sacrificial site of Skedemosse, Sweden (Boessneck *et al*. 1968, 37, Abb. 7). In terms of appraising prevalence, it is important that this specimen was recovered from a large assemblage that represented at least a hundred individuals.

Less dramatic looking lesions can also be observed on metapodia. A combination of inherited foot conformation and work-related single minor trauma may cause smaller or greater deformations. Minor trauma may cause the cortical expansion of bone leading to ossifying haematoma (Brothwell 2010, 128, fig. 5.22). In vernacular terminology splint is the name given to the ossification of ligaments between the metapodial bones of horse manifested by a bony swelling, usually on the medial side in the metacarpal region, caused by the fusion between the large 3rd metacarpus and the 2nd (or also the 4th) vestigial metapodial bones. Daugnora and Thomas (2005) reported splints as the most frequently occurring anomaly in 280 horse burials. In a systematic study on ten zoo specimens of the wild Przewalski horse Bendrey (2007, 209–210) has confirmed the empirical observation that fusion between the medially located 2nd and 3rd metacarpus is most frequently recorded. His results are in accordance with the static live weight distribution of horses and the fact that increasing mineralisation and decreasing vascularisation predispose older animals to this condition. The importance of Bendrey's work does not simply rest in having devised a scoring system for splint: his observations were made on wild horses in captivity that had never worked. This pattern reflects natural loading and aging but can by no means be attributed to draught exploitation or riding.

Bones of the carpal and especially the tarsal joint, located proximally from metapodia form a special topic. Smaller *exostoses* around these bones' articular surface have little functional significance. Clinically, they are known to occur spontaneously in 75% of older horses (Tamás 1987, 391). The overwhelming majority (7%) of radiographically detectable lesions in the feet of 803 modern horses occurred over nine years of age (Fleig and Hertsch 1992, 66, tab. 3). Graver forms of exostoses, however, may immobilise the joint and lead to complete fusion between bones. Spavin is ankylosis in the hock joint, common in horse, whose tarsal bones are the fewest in number among ungulates and their movements are more restricted than in even-toed livestock (Barneveld 1990, 1162). It remains a question whether advanced spavin in the left foot of the aforementioned 8–9-year-old male "shaman" horse from Keszthely with 17 ankylosed vertebrae was exacerbated by the grave general condition of the animal (Figure 12.9).

In phalanges, a similar type of periarthritis may cause the so-called high ring bone formed around the pastern joint, turning into a full fusion between the proximal and medium phalanges (Tamás 1987, 422, figs. 480–481). Low ring bone occurs on the distal end of the medium phalanx and the articular surface of the hoof bone. Although the pastern joint plays a key role in stabilizing the foot (Ratzlaff and White 1989), it takes part in relatively little dynamic motion (Chateau *et al*. 2002). Work-related strain on the extensor and flexor tendon branches, as well as on the collateral and distal sesamoidal ligaments play a role in ring bone formation. Chronic degenerative joint disease or trauma may likewise result in the excess growth of new bone to help stabilise the affected joint. This condition is not only well known clinically (Kardeván 1976, 630, fig. 602), but also on bones from archaeological sites such as

Figure 12.9. Dorsal (left) and plantar (right) views of the fused tarsal joint and metatarsus in the left foot of the "shaman" horse from Keszthely, Hungary.

Iron Age Skedemosse in Sweden (Boessneck *et al*. 1968, 41, Abb. 10–11). Navicular arthritis is a disease of the narrow, distal sesamoid bone in horse, wedged between the medium and distal phalanges. It occurs in individuals over four years of age and often is accompanied by arthropathy of the distal interphalangeal articulation. It begins as a degenerative and erosive lesion of the fibrocartilage on the tendinous surface of the bone. Synovitis develops later. Osteological symptoms include spurring and osteophyte formation on the proximal or distal borders and small lytic lesions in the distal border of the bone as illustrated in Baker and Brothwell (1980, 128, fig. 16). Large areas of bone matrix dissolution may appear in the centre of the bone and loss of cortical bone takes place over the flexor surface. Navicular disease is one of the most frequent but least understood causes of forelimb lameness in modern horse. It is attributed to improper foot conformation while the interruption of blood flow in the navicular region has also been proposed as a contributing factor (Stashak 2002, 664). Sidebone on the distal phalanx is a common condition in both working cattle and horses. It results from the ossification of the collateral cartilages. The front feet are most commonly affected.

12.5 Conclusions

Given the complexity of its research problems, animal palaeopathology may be compared to the proverbial "veterinary horse", traditionally used in demonstrating diverse maladies accumulated in a single beast. In addition to difficulties of diagnosis

using nothing but bone tissue that has a limited repertoire of symptoms of diverse aetiologies, horse palaeopathology is perhaps most plagued by "anthropogenic noise". The perception of horses is intimately linked to the way they are being treated throughout their lives and after death. *In vivo* treatment determines real-life disease prevalence, while *post mortem* handling strongly influences biostratinomy, the pre-depositional taphonomic history of horse finds. Burials of complete horses carry high quality osteological information. The decreasing degree of skeletal integrity, however, makes diagnosis and interpretation of lesions increasingly difficult in other types of archaeological deposits. When the numbers of isolated bone finds from cultural layers are plotted against assemblage sizes (NISP) at settlements from Eurasia on a broad time scale (in addition to cases mentioned in the text: Liepe 1958, 14; Lumpp 1967, Taf. II/8c; Müller 1967, 142; Taf. 1.4; Sauer-Neubert 1968, 33; Abb. 2a-b; Noddle *et al.* 1977, 66; Zawatka and Reichstein 1977, 110; Arbinger-Vogt 1978, 57; Kocks 1978, 47; Missel 1987, 81; Pfannhauser 1980, 105; Taf. 2.7; Steber 1986, 93; Taf. 1/Abb. 1.b; Teichert 1988, 188; Taf. 18.1; Reichstein 1990, 280; von den Driesch and Pöllath 2004, 32, Tab. 28, Abb. 9/5), the effect of LLN becomes evident. Sites showing high percentages of horse remains among the refuse bone as well as those where horse was rare in large assemblages offer more evidence of pathological specimens (Figure 12.10). Even in these cases, however, the occurrence of several bones with pathological lesions is rare. More interestingly, 21 of the 36 non-articulated pathological cases (two-thirds) summarised in this graph were observed on taphonomically resistant skeletal elements in the distal limb region including metapodia and phalanges. Spavin, a chronic disorder accompanied by dense osseous build-up in this region was recorded in nine cases (one-quarter), potentially indicative of the key role preservation plays in the degree to which pathological lesions can be identified in archaeological deposits (Bartosiewicz 2008a).

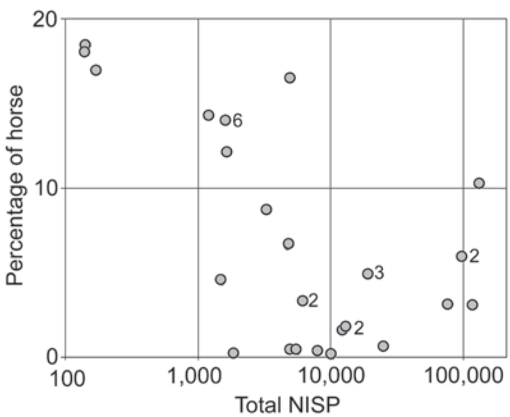

Figure 12.10. The numbers of isolated pathological horse bone finds from cultural layers shown in light of assemblage sizes (total NISP) and the percentage of horse remains from Hungary (14 sites) and the international literature (22 sites in the Appendix). Numbers within the graph indicate more than a single pathological specimen per site.

In this paper horses were singled out for study as their five levels of skeletal integrity can be easily distinguished in archaeological deposits. An inductive review of the manifestation of various diseases was presented using finds from Hungary and additional specimens from the international literature. Not even this material of considerable size would have permitted drafting an all-inclusive model of horse palaeopathology. The examples reviewed, however, helped pinpointing culturally determined taphonomic bias to be considered in future attempts in modelling the prevalence of animal disease in archaeology.

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Appendix 12.1:

The contribution of horse remains to various archaeozoological assemblages outside the Carpathian Basin

Site name, country	*Period*	*Total NISP*	*Horse %*	*Reference*
Breisach–Hochstetten, Germany (former BRD)	150–50 BC	6105	3.3	(Arbinger-Vogt 1978, 57)
Büyükkaya, Boğazköy–Hattuša, Turkey	E–M Iron Age	12,387	1.6	(von den Driesch and Pöllath 2004, 32, Tab. 28, Abb. 9/5)
Büyükkaya, Boğazköy–Hattuša, Turkey	Hittite–M Iron Age	5022	0.5	(von den Driesch and Pöllath 2004, 31, Tab. 28)
Cerro de la Encina, Monachil, Spain	questionable			(Friesch 1987, 63)
Niederrealta Cazis/Graubünden, Switzerland	13–14th *c.*	8024	0.3	(Lumpp 1967, Taf. II/8c)
Dannenberg, Germany (former BRD)	medieval 9th *c.*	141	18.4	(Kocks 1978, 47)
Weinberg in Hitzacker/Elbe, Germany (former BRD)	medieval 12th *c.*	10,287	0.1	(Kocks 1978, 47)
Lidar Höyük, Turkey	4 th *c.* BC–AD 3rd *c.*	131,710	10.3	(Kussinger 1988, 98)
Manching Germany (former BRD)	La Tène	118,510	3.1	(Liepe 1958, 14)

(Continued)

The contribution of horse remains to various archaeozoological assemblages outside the Carpathian Basin *(Continued)*

Site name, country	*Period*	*Total NISP*	*Horse %*	*Reference*
Hildesheim–Bavenstedt, Germany (former BRD)	AD 3–5th *c.*	4747	6.6	(Missel 1987, 81)
Lauriacum, Germany (former BRD)	AD 2nd *c.*	13,076	1.7	(Müller 1967, 142, Taf. 1/4)
LLantrithyd, S. Glamorgan, UK	medieval	1525	4.5	(Noddle *et al*. 1977: 66)
Burg Sponeck bei Jechtingen, Germany (former BRD)	Roman, late	25,438	0.6	(Pfannhauser 1980, 105, Taf. 2/7)
Archsumburg auf Sylt, Germany (former BRD)	Roman Empire	172	16.9	(Reichstein 1990, 280)
FeddersenWierde, Germany (former BRD)	German, 3rd *c.*	50,353	12.9	(Reichstein 1991, Taf. 18/1)
Hüfingen, Germany (former BRD)	Roman Empire	77,662	3.1	(Sauer-Neubert 1968, 33, Abb. 2a–b)
Bad Salzulfen, Germany (former BRD)	14–16th *c.*	560	99.9	(Schreiber 1989: 228–229, Abb. 1)
Takht-i Suleiman, Iran	13–14th *c.*	5669	0.4	(Steber 1986: 93, Taf. 1/Abb. 1/b)
Künzing–Quintana, Germany (former BRD)	Roman Empire	4089	4.0	(Swegat 1976, 82)
Dominsel Brandenburg/ Havel, Germany (former DDR)	Slavic, 10–12th *c.*	19,350	4.9	(Teichert 1988, 188)
Bentumersiel, Germany (former BRD)	Roman Empire	4977	16.5	(Zawatka and Reichstein 1977, 110)
Pizzica–Pantanello, Italy	late 5th–late 4th *c.* BC	1186	12.5	(Bökönyi 2010, 30)

13. From Arthrosis to Necrosis: Many, Many Pathological Chickens from the Avar Cemetery at Vienna Csokorgasse, Austria

Henriette Baron

In 1976 and 1977, construction work in the area of the Csokorgasse in Vienna (11th district) necessitated the excavation of a large Avar cemetery: 705 burials of the 7th and the 8th centuries were discovered. The Avars buried their dead with various burial goods among which animals and animal parts were abundant. The most commonly encountered animal in the Csokorgasse burials is the domestic chicken: remains of 323 individuals were found in 319 graves. Often the majority of the skeleton was present.

Given the large number of these bones (over 7000), it is unsurprising that various pathological lesions could be observed, ranging from minor joint alterations to fractures and even severe femur head necroses which must have caused inconceivable pain. A few individuals were affected on multiple parts of the skeleton. The closed find situation makes it possible to attribute these observations to hens and roosters of different ages and to check whether the egg-laying period may have played a role in the formation of pathological lesions.

Unfortunately, there is little literature on avian palaeopathology. Modern veterinary medicine focuses on pathologies caused by unnatural present-day husbandry practices (being not simply pathogenic, but almost pathological themselves). Hence, the documentation of this properly aged and sexed collection can contribute to a better understanding of health conditions in past chicken flocks.

13.1 Introduction

In 1976–1977, construction work in the area of the Csokorgasse in Vienna (11th district) necessitated the rescue excavation of a large Avar cemetery. On behalf of the Historical Museum Vienna (today called Wien Museum) the complete cemetery comprising 705 burials was excavated under the direction of Ludwig Streinz. The majority of finds still awaits archaeological examination but a catalogue of the burials already exists (Streinz 1977). The animal bone material was subject to my PhD thesis. Recently, Falko Daim and Ludwig Streinz have worked out a chorology of the cemetery (which will be included in the site monograph: Baron 2018). According to this, the cemetery was continuously in use from the second quarter of the 7th century (Early Avar Period II) until the end of the 8th century (Late Avar Period II and III, Figure 13.1). As was common in these

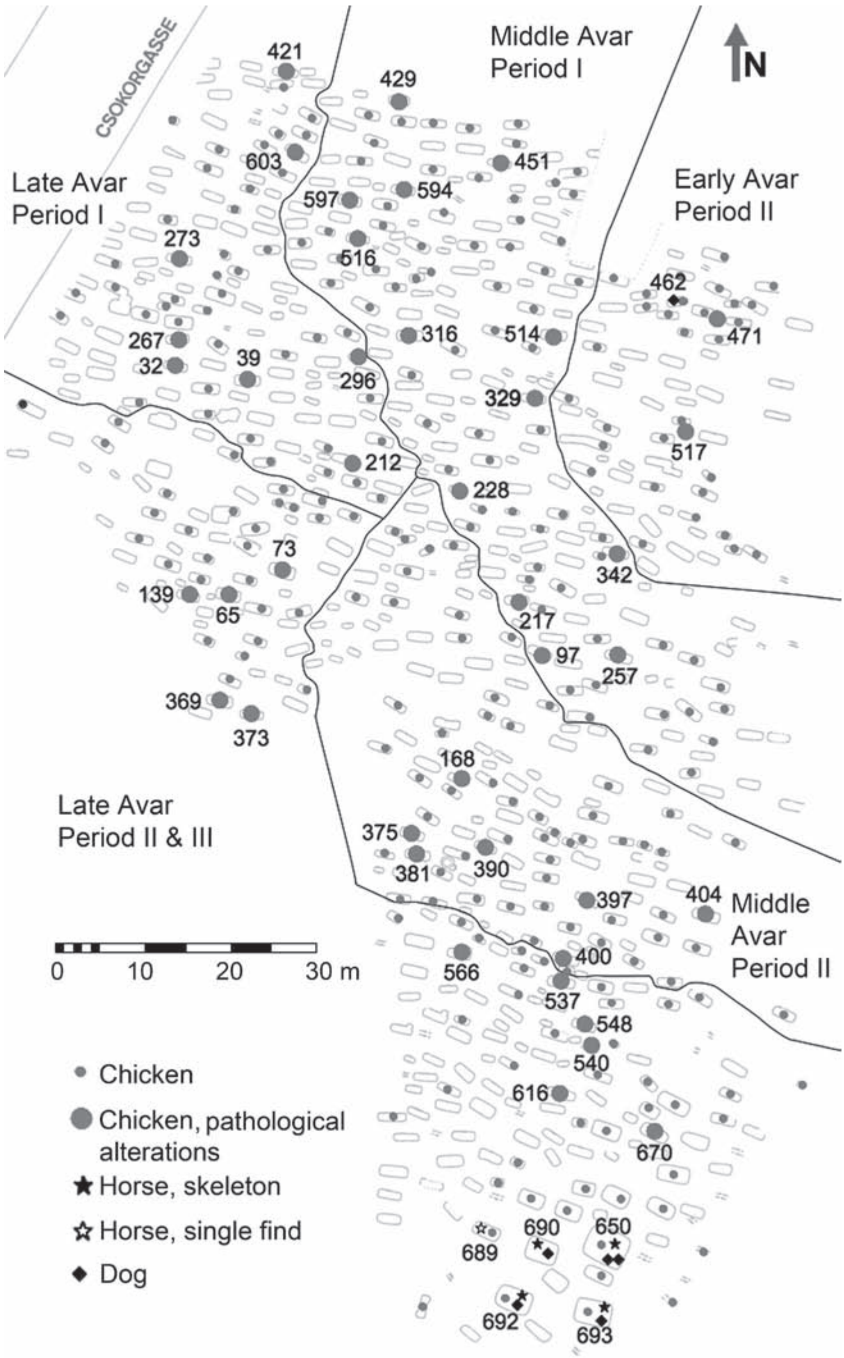

Figure 13.1. Vienna Csokorgasse. Map of the cemetery, showing the finds of chickens, horses and dogs.

periods, inhumation graves are laid out in a West–East orientation and were endowed with a variety of grave goods, frequently including animals and animal parts.

Almost three-quarters, 491 of the 705 burials (70%) contained animal bone finds. The most commonly represented animal species in the Csokorgasse burials is domestic chicken (*Gallus gallus* f. *domestica*): the remains of 323 individuals were found in 319 graves (45%). Often large parts of the skeleton are present. In almost as many burials (313, that is 44%) bones of sheep (*Ovis ammon* f. *aries*) or goat (*Capra aegagrus* f. *hircus*) were found, in most cases represented by the thigh bone (femur). The remains of other species occurred less frequently. Cattle (*Bos primigenius* f. *taurus*) was found in 240 burials (34%), while pig (*Sus scrofa* f. *domestica*) appeared only in 84 burials (12%). Apart from these, remains of geese (*Anser anser*), be they domestic or wild, as well as of different wild birds were identified. They included western jackdaw (*Corvus monedula*), northern goshawk (*Accipiter gentilis*), Eurasian skylark (*Alauda arvensis*), rock dove (*Columba* cf. *livia*), white-tailed eagle (*Haliaeetus albicilla*), smew(*Mergus* cf. *albellus*), grey partridge (*Perdix perdix*), and Eurasian woodcock (*Scolopax rusticola*). In addition bones of a variety of carpfish species (Cyprinidae), pike (*Esox lucius*) and catfish (*Silurus glanis*) were found.

Four particularly rich Late Avar burials in the South (burials 650, 690, 692 and 693, Figure 13.1) contained the skeletons of a horse (*Equus ferus* f. *caballus*). Three of these each included a dog (*Canis lupus* f. *familiaris*) skeleton (and burial 692 at least a dog tibia). The pathological symptoms observed on the horses and dogs are subject to another paper in this volume.

This paper deals with pathological changes observed in the chicken skeleton. Little is known about avian palaeopathology, due to a number of reasons. On the one hand, bird finds are comparably rare, because they are small and easily overlooked during the course of excavations. Furthermore, bird bones often remain unanalysed because their huge taxonomic variability makes their identification difficult or even impossible. The share of pathologically modified bones tends to be small among bird bone finds, because these animals often did not reach a high age. The chances of survival after severe injuries or diseases are small for wild birds, while domestic birds were often killed at a young age, or perhaps when they showed signs of weakness. Given their comparably low commercial value and their high rate of reproduction, these animals were usually seen as dispensable.

Most archaeozoological publications on pathological lesions in birds focus on fractures on the one hand and avian osteopetrosis – a condition not encountered in the Csokorgasse material – on the other (Peters 1997, 47–49; Baker and Brothwell 1980, 60–62; Brothwell 2002; Gál 2006, 56–57; 2008b). Some studies try to take into account other aspects of pathological lesions but have few published data to draw on (Gál 2008a; Bartosiewicz and Gál 2013). David R. Wise and Barry H. Thorp give useful overviews from the perspective of veterinary medicine (Wise 1975; Thorp 1994). The paper by Bruce M. Rothschild and Robin K. Panza (Rothschild and Panza 2005) also offers some practical illustrations to work with.

Given the scarcity of information on bird palaeopathology in archaeozoological materials, this paper aims to close this gap by presenting a highly informative, pathologically affected chicken bone assemblage. The value of this material does not only lie in the pathological lesions observed. These chickens remains originate from

closed burial finds and not commingled food refuse as is generally the case with settlement assemblages. Hence, the pathological changes observed can be contextualised in three ways:

1) In most cases other bones of the skeletons are present. This allows to check whether the pathological condition was systemic, *i. e.* influenced other parts of the skeleton.
2) It was possible to sex most individuals by means of various methods (see below) and the presence of numerous skeletal elements often allowed for the detection of medullary bone in females, a sign for the egg-laying period.
3) The age of death could be narrowed down for most individuals, as ossification in large parts of the skeleton could be taken into account simultaneously.

Given the relevance of this contextual information, the ageing and sexing methods as well as observations regarding the completeness of the skeletons are detailed in this study.

13.2 Material and method

13.2.1 Chicken bone counts

Except for only few burials, only one chicken occurred per burial (323 chicken in 319 burials), hence a clear attribution of the skeletal elements to a single individual was possible in almost all cases. The chicken bone assemblage comprises 9121 bone fragments. These originate from 7223 skeletal elements of 323 individuals, weighing 4435 g. The average number of preserved skeletal elements per individual is 20.

13.2.2 Identification and recording

The identification of the finds was carried out in the archaeozoological reference collection of the Centre for Baltic and Scandinavian Archaeology (ZBSA) in Schleswig, Germany. Each bone in each skeleton was registered in a database using the following 19 parameters:

1) burial number,
2) individual ID,
3) number of fragments,
4) number of elements (for multiple elements such as vertebrae cervicales, ribs, ossa sternocostalia or phalanges),
5) bone weight,
6) species,
7) skeletal element,
8) body side,
9) degree of ossification,
10) measurability,

11) amount of bone preserved,
12) part of bone preserved,
13) damage,
14) colour,
15) texture,
16) cut marks,
17) fire marks,
18) pathological lesions,
19) miscellaneous observations.

All bones sufficiently well preserved were measured following the standard laid out in the handbook by Angela von den Driesch (1976; measurements are given in detail in Baron 2018).

13.2.3 Completeness of the skeletons

Most chickens (at least 169, *i.e*. 52%) were interred as a whole and found in anatomical order, even though in 98 cases (of the 169 skeletons) certain body parts had been removed before, for instance the head, the feet (tarsometatarsus, phalanges posteriores), or the tips of the wings (carpometacarpus, phalanges anteriores). In a few cases (25 individuals) of more or less complete skeletons a single body part, *e.g*. a leg or a wing, was missing. It seems likely that these had been removed before the animal was put in the grave and that their lack is not due to post-depositional loss. Of another 89 chickens (28%) only single body parts were interred with the dead, in most cases legs or wings. Finally, of 65 individuals (20%) more than one body part but still a very incomplete skeleton was present – in these cases it is unclear whether such finds represent something like a portion of a stew or are the badly preserved remains of chickens interred as more-or-less complete birds.

13.2.4 Ageing

Chickens could be allotted to four age groups: adult, subadult, juvenile, and infantile. Adult animals show a completely ossified skeleton. These birds should have reached an age of at least six months. The division of the three age groups for young animals was based on the following criteria: Epiphyses in the skeleton of subadult animals are widely ossified or at least in the process of ossifying. The three elements of the pelvis are fused and the wing skeleton is largely ossifying, while the leg skeleton in many individuals is only lightly ossified. According to published observations on the skeletal development of chickens, these animals could have reached an age of 4 to 6 months (Peters 1997, 51–52). The juvenile individuals do not yet have a fused pelvis and neither the wing nor the leg skeleton are ossified to a noteworthy degree. Such birds, as well as one tiny infantile chick (differentiated from the juvenile chickens because of its minute size), must have died younger than 4 months old.

Of the 323 individuals 215 (67%) were classified as adult. The remaining 108 individuals (33%) show incomplete skeletal ossification. Of these, 48 (15% of all chickens) were classified as subadult, 59 (18%) as juvenile and one individual (0.3%) as infantile.

13.2.5 Sexing

The sexing of the subadult and adult skeletons was primarily carried out on the basis of measurements. Bivariate plots of long bone measurements were used in differentiating between two size groups: a bulk of medium sized to small hens of variable bone widths and a small and more evenly distributed group of larger roosters. For some skeletons several skeletal elements were available for this sexing technique, for others only one. Observations on the occurrence of medullary bone and of spurs or "spur scars" on the tarsometatarsus were used in adjusting the results of metrical sexing.

For 191 of the 265 subadult to adult chickens (that is 72% of these two age groups and 59% of all chickens) metrical sexing provided feasible results. Forty-eight of these animals (25%) were identified as male, and two more as possibly male. The majority, 140 of the animals (73%), were identified as female, plus one possibly female individual.

Medullary bone, a clear proof of females, was observed in 80 hens. For 20 of these, sexing relies solely on this observation. For the other 60 the presence of medullary bone confirms the results of sexing carried out on an osteometric basis. The share of 57% of hens killed during the egg-laying period (80 of the 140 females showing medullary bone formation) points to intensive egg production.

At least one tarsometatarsus was found for 136 of the 323 chicken skeletons. Of these 21 are juvenile chicken where no spur development or spur scar tissue is to be expected. Among the 20 subadult individuals with a tarsometatarsus there were two with a slight unevenness at the respective section of the diaphysis, possibly indicative of young roosters. Three subadult animals identified metrically as roosters did not (yet) show such morphological signs. In another seven of the 15 remaining subadult individuals the identifiable section of the bone diaphysis was missing. Among the remaining eight there were six individuals otherwise identified as hens. In the adult birds at least a scar of the spur can be expected. One individual could be identified as male solely by its 11.6 mm long spur. Another 26 adult individuals identified metrically as roosters having at least one tarsometatarsus preserved. Of these, ten carried a spur, their lengths ranging from 9.9 to 26.5 mm. Another six roosters show a marked bulge on the diaphysis but no spur. One of these animals had loose spurs, sitting on the *processus calcaris* but not yet fused with the shaft of the tarsometatarsus. Five animals show a small bulge on the diaphysis but no spur. Meanwhile one very large individual does not show the slightest trace of a spur. Its enormous size, however, does clearly suggest it being a male.

13.2.6 Recording of pathological lesions

The palaeopathological examination of bones was carried out macroscopically. No medical imaging techniques were applied. The recording of the pathological symptoms is primarily descriptive. The weak state of research on avian palaeopathology does not allow for waterproof diagnoses. Furthermore, there is no existing standard for the recording of pathological lesions on the avian skeleton. Hence, Tony Waldron's advice was followed: "In many cases all that one will be able to do is to describe (and preferably photograph) the abnormality" (Waldron 2009, 60).

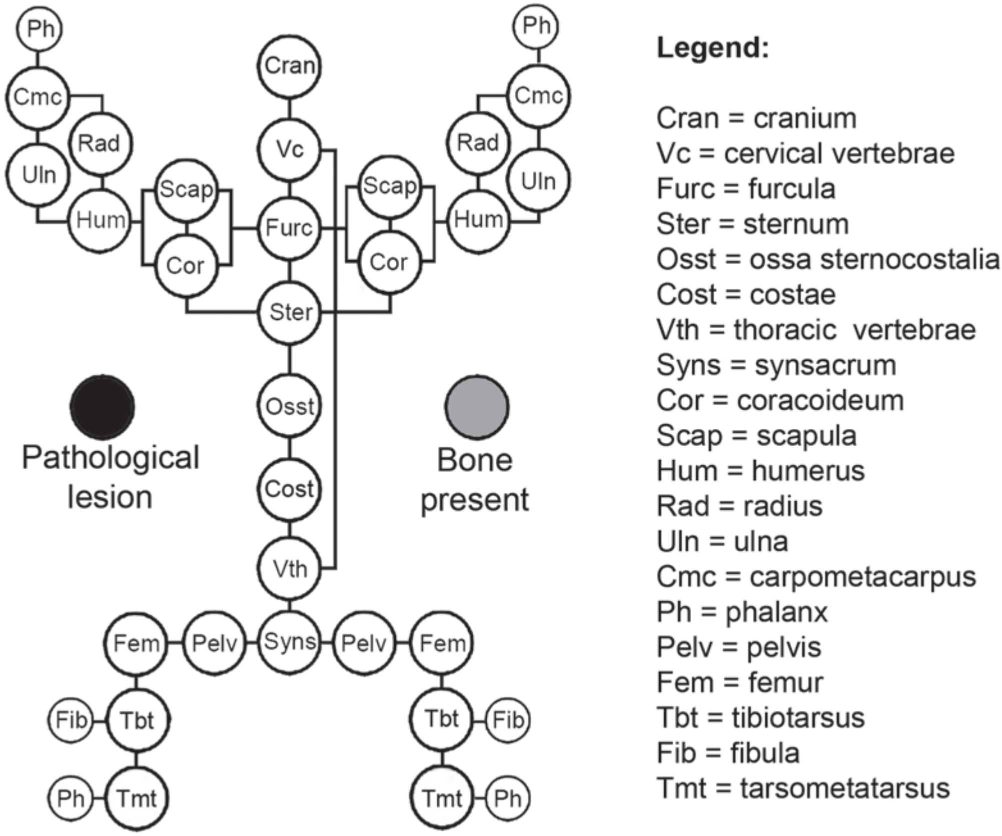

Figure 13.2. Matrix of the chicken skeleton (dorsal view) used in illustrating the anatomical location of lesions in the following figures. Black: pathologically modified bone, grey: skeletal elements present.

The completeness of skeletons and anatomical location of pathological lesions were mapped in the illustrations of this paper following the skeletal template detailed in Figure 13.2. That skeleton is shown in a dorsal view with major types of bones marked by circles.

13.3 Results of the palaeopathological analysis

13.3.1 General overview

Forty of the 323 individuals (12%) show slight to severe pathological-anatomical alterations. Most of these individuals (20) have only one affected skeletal element, ten have two bones with alterations, while another nine individuals show three or more altered skeletal elements. These include three individuals with three pathological bones,

two with four bones, two with five bones, one with seven bones and one with eleven bones.

The overall sex ratio in the material is three hens to one rooster. Among the pathologically afflicted animals the share of hens is somewhat higher: four hens to one rooster. The "polymorbid" animals with at least three affected elements that could be sexed were all females. Given the high share of laying hens in the material, this could be due to an osteoporotic decrease of the bone density resulting from egg shell production (*c*. 2 g calcium per egg has to be generated within *c*. 13 hours; Thorp 1994, 220) or to worse keeping conditions for hatching hens.

The pathological changes encountered in the material can be roughly grouped as follows: On 36 bones only light exostoses or lipping of joint surfaces could be detected. These are not necessarily pathological deformations in the strict sense, but rather anatomical alterations. Thirty-two bones showed symptoms of inflammation and/or infectious disease. Among these, in 12 cases the hip joint was affected. Fourteen bones show traumatic lesions, and nine are deformed, probably at least in part due to developmental disorders, while two skeletal elements show other, miscellaneous alterations.

13.3.2 Description of the pathological changes observed

Inv. no. 41032/97, male, subadult, Late Avar Period I

The condylus medialis of the right tarsometatarsus is shortened, possibly as a result of a fracture accompanied by a *dislocatio ad longitudinem cum contractione*. The *condylus medialis* is located where usually the metatarsus I can be found. A slight bulge in the distal part of the bone could stem from an inflammatory response to trauma.

Inv. no. 41039/99, female, adult, Late Avar Period I (Figure 13.3A)

The *crista sterni* is axially crooked. In addition, the caudal section of the sternum bends to a dorsal direction. As the animal died in adult age and the sternum was completely ossified, these deformations certainly did not occur after deposition. Furthermore, this hen shows a healed fracture of the left ulna accompanied by a slight *dislocatio adperipheriam*. The left femur displays a small bone formation on the cranial edge of the *condylus lateralis*, possibly an ossified sinew or muscle insertion.

Inv. no. 41065/99, female, adult, Late Avar Period II&III (Figure 13.3B)

One left rib shows a nodule in its dorsal section, *i. e.* the area close to the vertebral column. The nodule does not look like the result of a fracture. Hence it could be due to an infection of the *thorax* (avian tuberculosis?). The sixth thoracic vertebra displays lipping on the edges of the articular surfaces, possibly due to the advanced age of this individual (not pictured). The same applies for a lipping of the articular surface of the right tarsometatarsus, at the point of articulation for metatarsus I. The proximal section of the left femur also displays exostoses. They are most notable underneath the *caput femoris* and occur in the corresponding area of the left pelvis as well. These latter exostoses even began to lead to a closure of the *foramen obturatum*.

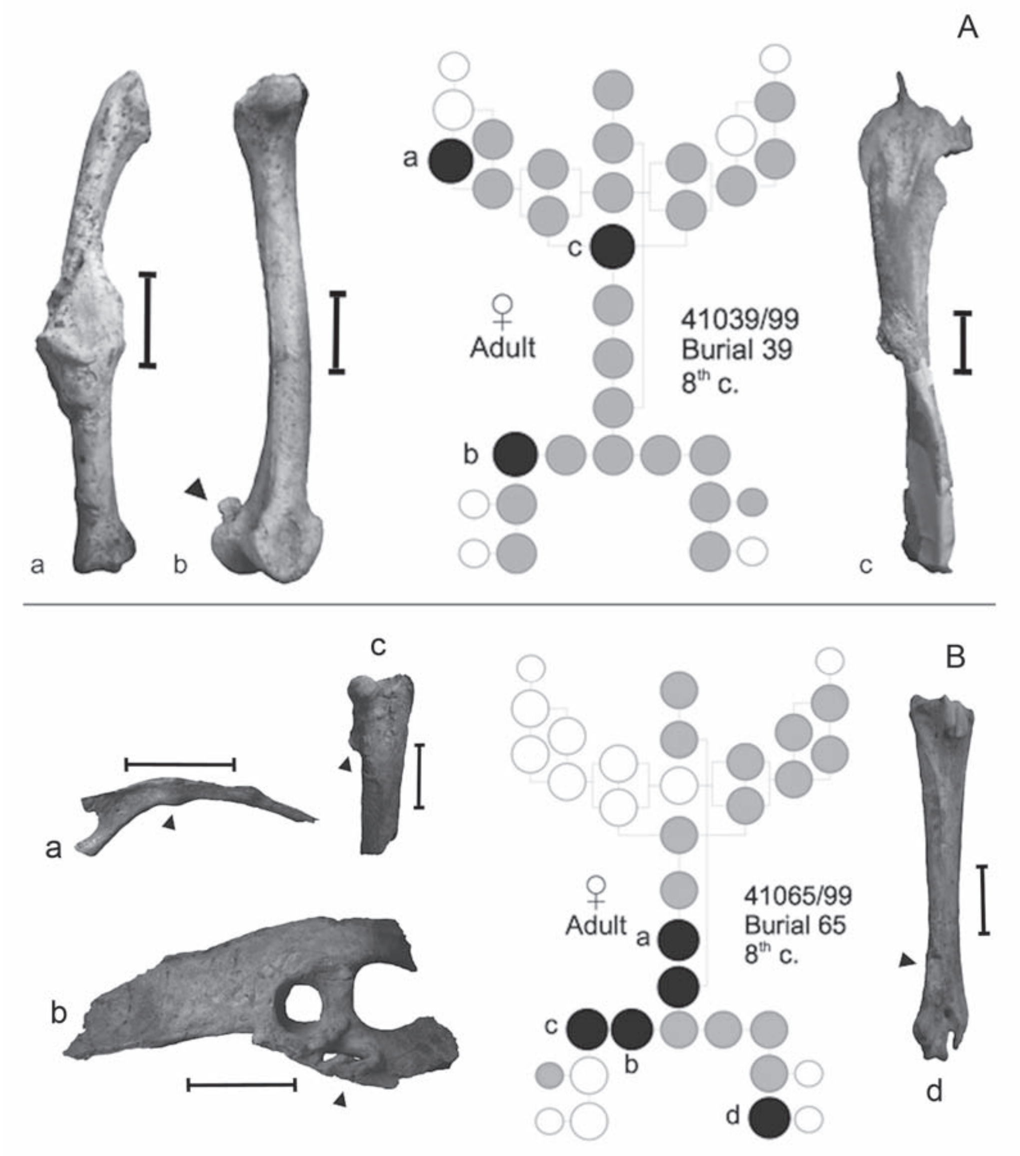

Figure 13.3. Vienna Csokorgasse. Pathological chicken bones from burials 39, 8th c. *(A) and 65, 8th* c. *(B).Scale: 1 cm.*

Inv. no. 41073/97, female, adult, Late Avar Period II and III
The small process located on the right carpometacarpus distally from the os carpometacarpale III shows slight new bone formation which led to a swelling of this bone section. Furthermore, the small gap gradually closing in the fusion process of

metatarsals III and IV, remains partially open in the left tarsometatarsus. Neither of these two anomalies, however, can be considered pathologies in the strict sense.

Inv. no. 41097/98, female, adult, Middle Avar Period I (Figure 13.4A)
A right rib shows a nodule in its dorsal section towards the vertebral column (see also Inv. no. 41065/99 (Figure 13.3B). Furthermore, the left femur underneath the *caput* as well as the corresponding left pelvis underneath the *acetabulum* display exostoses.

Inv. no. 41139/98, female, adult, Late Avar Period II&III
The *processus coracoideus* of the left scapula displays light exostoses.

Inv. no. 41168/98, female, adult, Middle Avar Period II (Figure 13.4B)
The notarium (*i.e*. the fused vertebrae thoracicae 2 to 5) are curved laterally to the right side. Such a condition is usually called scoliosis and can be conditioned either genetically or by an infection (Thorp 1994, 208; Wise 1975, 7).

Inv. no. 41212/99, female, adult, Late Avar Period I
The right scapula is broken in the middle of the shaft. Only the distal part is available. The fracture site displays bone proliferations caused by inflammatory processes such as osteitis or osteomyelitis (these two inflammations are difficult to tell apart. Osteomyelitis is the inflammation of the bone marrow which frequently follows osteitis, *i. e.* an inflammation of the bone matter). These inflammations often result from infections that occur after compound fractures because bacteria can enter easily into the wound (Baker and Brothwell 1980, 72).

Inv. no. 41217/95, female, adult, Middle Avar Period I (Figure 13.5)
Two delicate bones, the right os pubis, and the left furcula show well healed fractures. The left carpometacarpus distally carries slight exostoses (see Inv. no. 41073/97). The proximal left femur underneath the *caput* as well as the left pelvis underneath the *acetabulum* show exostoses (see Inv. no. 41065/99 Figure 13.3B).

Inv. no. 41228/98, sex indet., subadult, Middle Avar Period I
The distal section of the right carpometacarpus shows a large bone formation between the ossa carpometacarpalia II and III, as well as some planar lytic lesions that point to an infection (osteomyelitis).

Inv. no. 41257/97, male, adult, Middle Avar Period I
The long spur of the left tarsometatarsus is pointed upward. Even though conditions like this are known to occur in old individuals and are not seen as pathological, it is noteworthy that this specimen is the only one in the studied material. Other, even longer spurs do not show this deformation. Two right ribs show a slight lipping distally on the sternocostal articular surface.

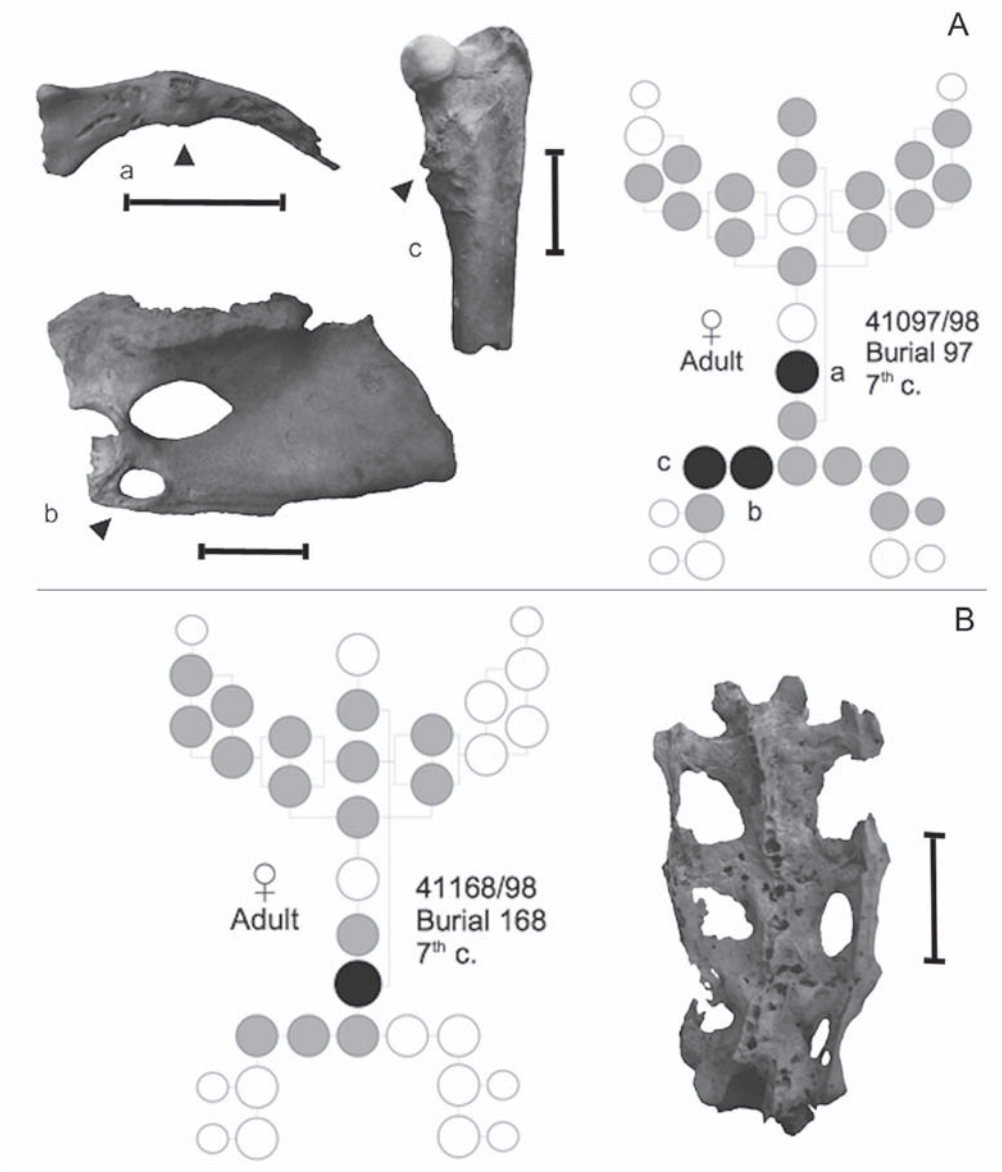

Figure 13.4. Vienna Csokorgasse. Pathological chicken bones from burials 97, 7th c. *(A) and 168, 7th* c. *(B). Scale: 1 cm.*

Inv. no. 41267/97, sex indet., subadult, Late Avar Period I
The right scapula is massively deformed proximally where it articulates with the coracoid. The intensive formation of new, spongy bone can probably be linked to a

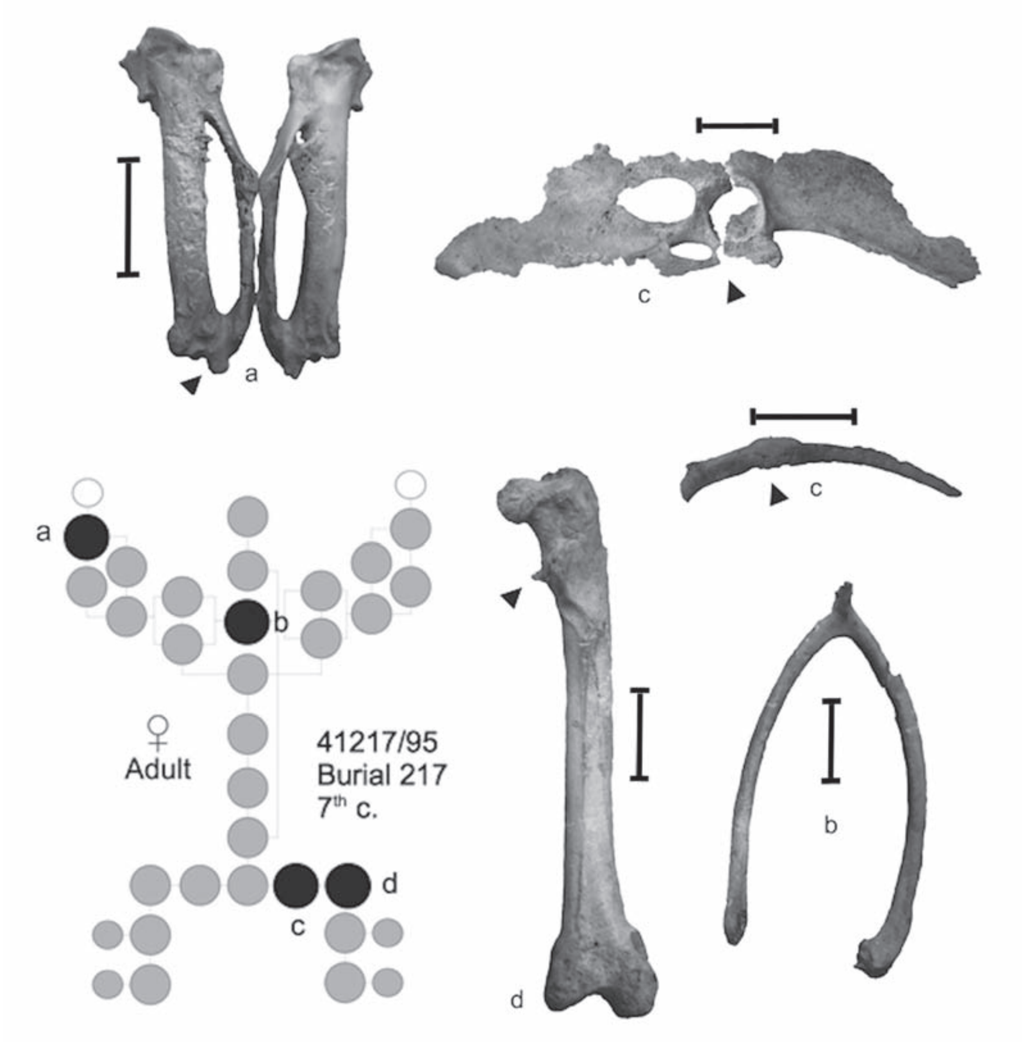

Figure 13.5. Vienna Csokorgasse. Pathological chicken bones from burial 217, 7th c. *Scale: 1 cm.*

severe inflammation of the joint, e.g., in consequence of an infection, rather than to a fracture.

Inv. no. 41273/98, female, subadult, Late Avar Period I
The right scapula is broadened proximally underneath the *processus coracoideus*. Underneath this section bone lesions can be detected which are obviously not a result of post-depositional taphonomic processes but of an inflammation. Perhaps this condition represents a well-healed fracture with subsequent infection.

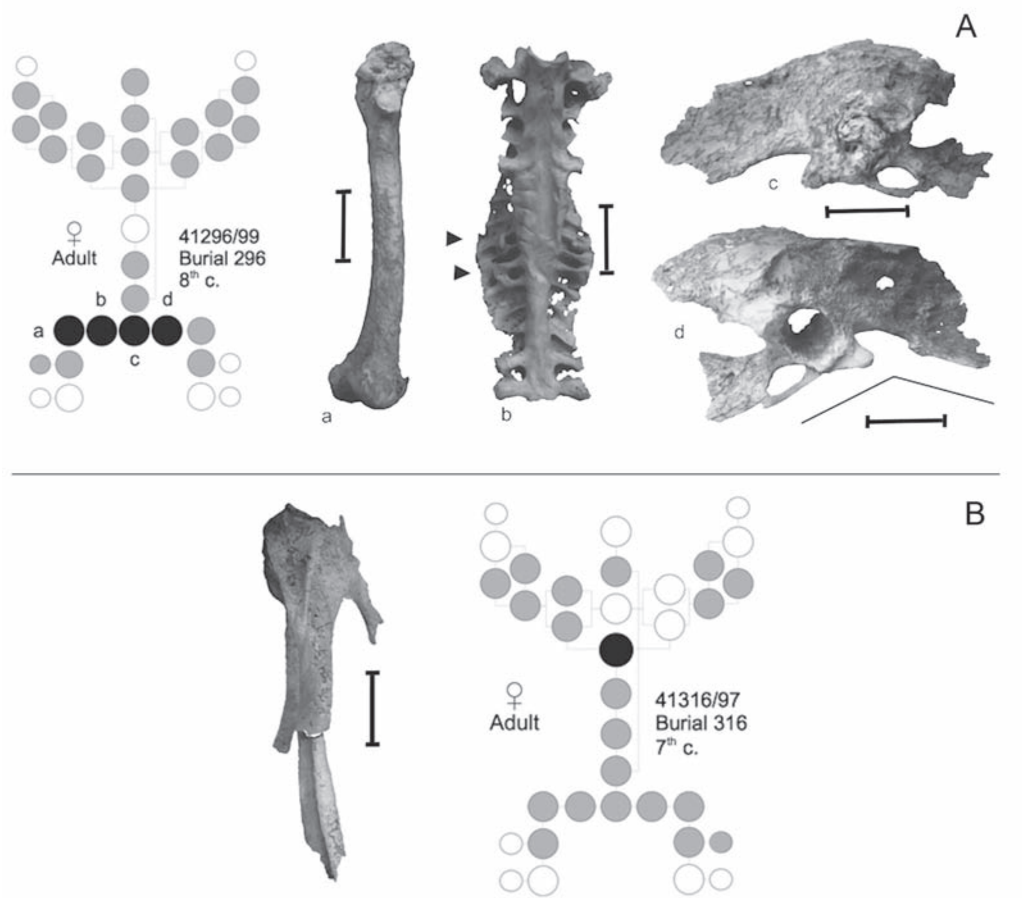

Figure 13.6. Vienna Csokorgasse. Pathological chicken bones from burials 296, 8th c. *(A) and 316, 7th* c. *(B). Scale: 1 cm.*

Inv. no. 41296/99, female, adult, Late Avar Period I (Figure 13.6A)
This chicken suffered from a femoral head necrosis, the consequences of which can be seen in the skeletal elements of the whole pelvic area. For this case the wider term of "proximal femur degeneration" (terminology: Thorp 1994, 216) needs not to be applied, because it is in fact primarily the *caput* which is affected. Due to lytic processes the *caput* has been detached from the femur and has fused with the *acetabulum* of the pelvis. The improper posture resulting from this painful necrosis of the left femur led to a curvature of the right pelvis and also left marks on the synsacrum.

Inv. no. 41316/97, female, adult, Middle Avar Period I (Figure 13.6B)
The *crista sterni* (see Inv. no. 41039/99 Figure 13.3A) of this adult hen is markedly distorted.

Inv. no. 41329/98, female, adult, Middle Avar Period I
This hen also displays a crooked keel of the sternum, but only slightly. The left ulna also looks a little crooked and shows a few small dents along its diaphysis. These could be marks of healed lesions, perhaps resulting from inflammations of the bone or parts of it (marrow, periosteum) or from trauma (for instance a bite).

Inv. no. 41369/96&99, male, adult, Late Avar Period II and III
The right femur is proximally thickened. Exostoses occur in the area of the *trochanter maior* as well as around the *caput femoris*. These alterations resulted in a shortening of the bone.

Inv. no. 41373/98, female, adult, Late Avar Period II and III
Exostoses all around the *acetabulum* of the right pelvis of this laying hen point to arthritic alterations of the hip joint.

Inv. no. 41375/98, female, adult, Middle Avar Period II
The right scapula shows a fracture with a subsequent heavy infectionin its proximal half. This led to a marked malformation of the fragment edges of the two halves. The distal point of the bone also seems to have been broken off. The inflammatory processes led to a formation of bone matter on the adjoining right coracoid bone.

Inv. no. 41381/97, sex indet., subadult, Middle Avar Period II
The badly preserved left pelvis displays a markedly thickened and broadened ventral acetabular rim, possibly as a result of massive strain on the hip joint.

Inv. no. 41390/98, female, adult, Middle Avar Period II
The skeleton of this hen shows exostoses on a couple of elements, *i. e.* the left *processus articularis cranialis* of a vertebra cervicalis, the *capitulum costae* of a right rib and the adjoining notarium, bulging exostoses underneath the heads of both femora, and medially in the proximal section of the left tibiotarsus. These could be due to an advanced age in connection with a comparably high body weight. Furthermore, as a consequence of a fracture the left coracoid has formed a bony callus bridge towards the furcula.

Inv. no. 41397/98, female, adult, Middle Avar Period II (Figure 13.7A)
The *caput* of the right femur has become necrotic, in all likelihood resulting from an infection. The bone matter has dissolved completely (cf. Inv. no. 41296/99, Figure 13.6A). The pelvis of the respective body side is missing, but it can be expected that this, too, showed pathological alterations. Slight exostoses have formed at the contact point of the metatarsus I on the tarsometatarsus (not pictured).

Inv. no. 41400/99, female, adult, Middle Avar Period II
The left coracoid healed with a considerable formation of bony callus and was massively dislocated as a consequence of a fracture. The bone is heavily distorted and thickened, its

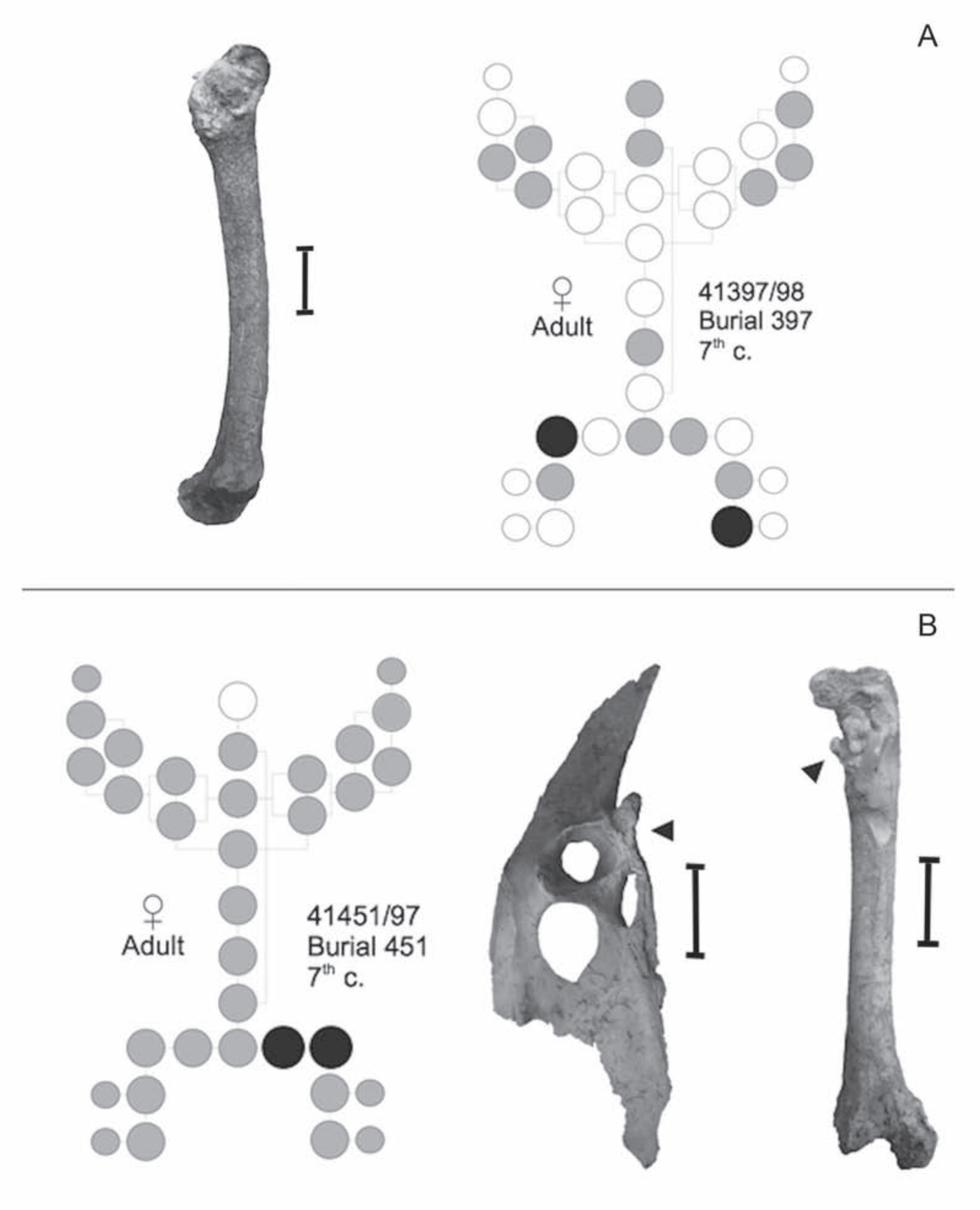

Figure 13.7. Vienna Csokorgasse. Pathological chicken bones from burials 397, 7th c. *(A) and 451, 7th* c. *(B). Scale: 1 cm.*

distal section fused ventrally of the actual articular surface with the sternum (however, they were detached from each other in the deposit).

Inv. no. 41404/98, male, adult, Middle Avar Period II
The left-hand side of the *crista sterni* shows a rounded roughness which could result from periostitis.

Inv. no. 41421/98, sex indet., juvenile, Late Avar Period I
The unfused right tibiotarsus of this young chicken shows distally a sidewise bulging margin which involves a coarse spongy tissue. This may have resulted from an inflammation (periostitis, osteitis).

Inv. no. 41429/99, female, adult, Middle Avar Period I
The furcula was broken on the left side in the proximal third and healed with a slight thickening of this delicate bone. The scapulae of both body sides show slight exostoses in their proximal sections.

Inv. no. 41451/97, female, adult, Middle Avar Period I (Figure 13.7B)
Massive bone formations have developed on the right femur medially underneath the *caput*. The corresponding area of the *acetabulum* of the right pelvis is also affected by the same process. These lesions probably represent an early stage of an infectious proximal femoral head degeneration (cf. Inv. no. 41296/99, Figure 13.6A).

Inv. no. 41471/99, female, adult, Early Avar Period II
A small coarse embossment of only a few millimetres diameter can be found in the middle of the diaphysis of the left humerus. This can be interpreted as a small (benign or malign) bone tumour. Furthermore, the *caput* of the left femur seems to be slightly indented.

Inv. no. 41514/98, female, adult, Middle Avar Period I
The *trochanter maior* of the left femur displays slight coarseness on the medial side underneath the *caput*, possibly as a result of inflammatory processes.

Inv. no. 41516/99, sex indet., juvenile, Middle Avar Period I
The left radius as well as the ulna are pathologically deformed in their proximal sections. Both are distorted, the ulna even more heavily. The radius has formed a bony spike in its proximal third. This seems to be the result of a poorly healed fracture of the wing with a *dislocatio ad longitudinem cum contractione*.

Inv. no. 41517/99, sex indet., juvenile, Early Avar Period II
The furcula of the young individual is massively contracted inward in its cranial portion. As the animal died young and its bones have not been completely mineralised, this condition could have been caused post-depositionally.

Inv. no. 41537/98, male, adult, Late Avar Period II and III
The articular surface of the right scapula displays slight exostoses.

Inv. no. 41540/98, sex indet., juvenile, Late Avar Period II and III
The caudal end of the *crista sterni* shows on its right side coarsenesses, malformation as well as lytic lesions. This case is certainly a result of a bone inflammation.

Inv. no. 41548/97, male, subadult, Late Avar Period II&III
Slight lytic lesions are visible on the inside of the left *acetabulum pelvis*.

Inv. no. 41566/97, female, adult, Late Avar Period II&III
The articular surfaces of both scapulae show distinct exostoses.

Inv. no. 41594/99, female, adult, Middle Avar Period I
The distal tip of the left scapula is slightly thickened. This can be seen rather as an anatomical than a pathological alteration.

Inv. no. 41597/98, female, adult, Middle Avar Period I (Figure 13.8A)
The left tarsometatarsus is proximally thickened like a club.

Inv. no. 41603/99, female, adult, Late Avar Period I (Figure 13.8B)
The skeleton of this hen shows arthritic exostoses on several skeletal elements. These could result from inflammations that resulted from strong cartilaginous abrasion. Hence, they show lippings on the articular surfaces of the scapula and coracoid, as well as on the distal condyles of the tarsometarsus. The rudimentary os metacarpale I on the proximal carpometacarpalia is enlarged. A right rib displays an exostotic broadening of the *capitulum* and *tuberculum costae*. Its counterpart on the notarium, shows analogous broadenings of its articular surfaces. The proximal part of the right femur has formed a thick bulge on the medial side. The respective pelvis of this body side also displays bulging thickenings of the whole acetabular rim. The *acetabulum* itself is almost completely filled by massive bony callus which extends into the inside of the pelvis. Nodules on the middle third of two right ribs should either stem from healed fractures or from an infection of the respiratory system (cf. Inv. no. 41065/99 Figure 13.3B).

Inv. no. 41616/98, female, adult, Late Avar Period II and III (Figure 13.9A)
The right hand pelvis developed exostoses underneath the *acetabulum* and the left tarsometatarsus shows broadened condyles. Both point to physical stress. Furthermore, the right wing was broken in the area of the zygopodium. Both the radius and ulna were severed and did not heal even though bony callus was formed. The caudal section of the *crista sterni* displays a healed compression fracture possibly caused by a blow from the left, which led to an indentation of the bony edge of the keel.

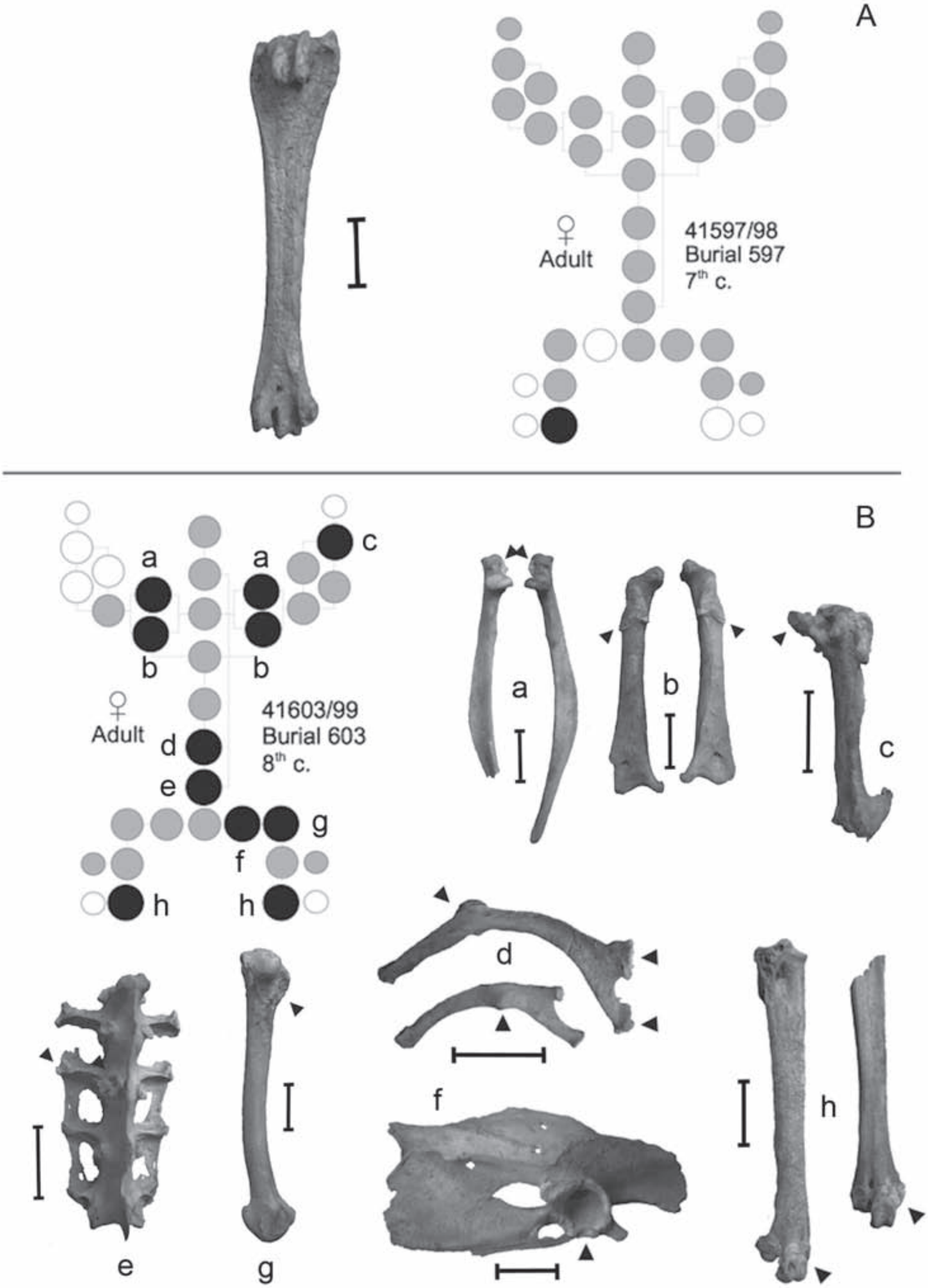

Figure 13.8. Vienna Csokorgasse. Pathological chicken bones from burials 597, 7th c. *(A) and 603, 8th* c. *(B). Scale: 1 cm.*

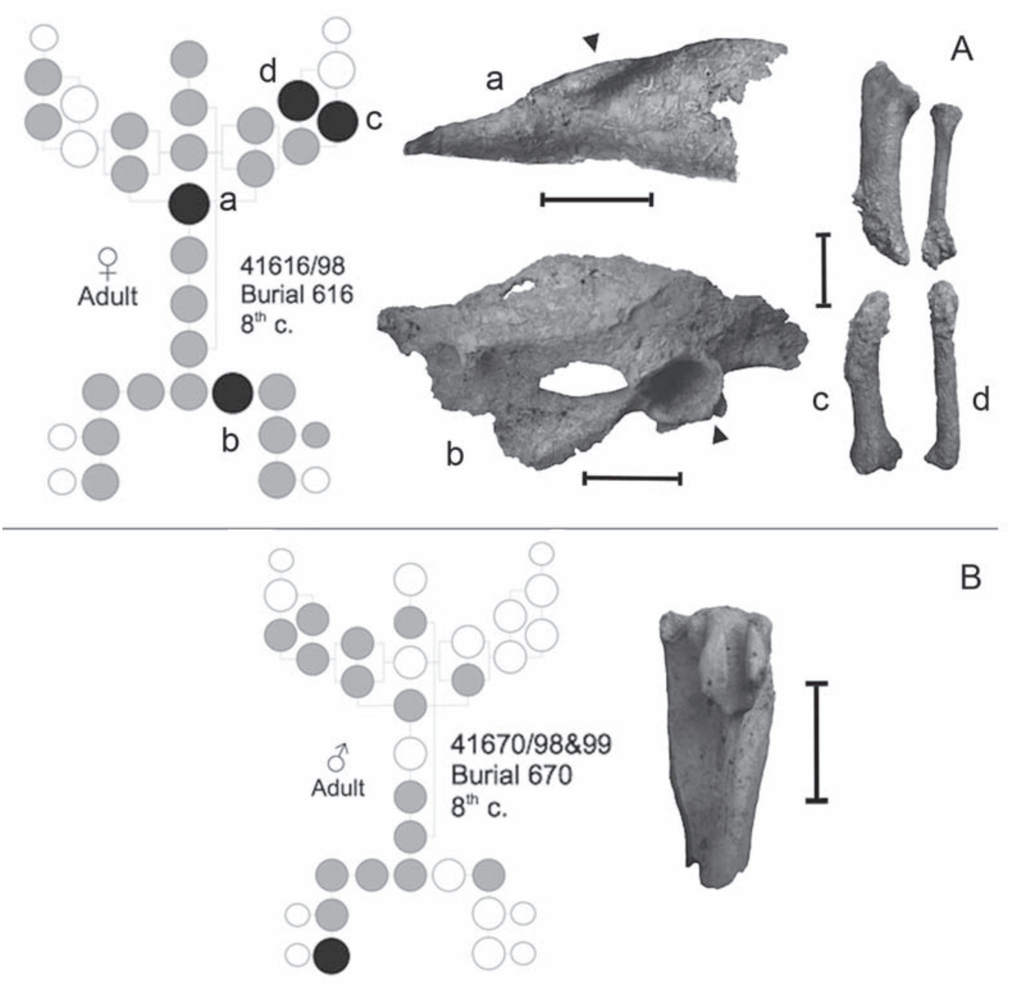

Figure 13.9. Vienna Csokorgasse. Pathological chicken bones from burials 616, 8th c. *(A) and 670, 8th* c. *(B). Scale: 1 cm.*

Inv. no. 41670/98&99, male, adult, Late Avar Period II&III (Figure 13.9B)
The left tarsometatarsus is proximally thickened like a club (cf. Inv. no. 41597/98, Figure 13.8A).

13.4 Discussion

In the following, a selection of the conditions shall be discussed with regard to the contextualising information that we have.

13.4.1. Crooked keel

The crooked keel commonly occurs even today. It still is unclear whether this distortion is due to certain ways of perching at an age when the sternum is not yet completely ossified or whether it is caused by nutritional deficiencies (Waldron 2009, 56). Erika Gál follows the second opinion and interprets them as possible symptom of rickets (Gál 2008a, 46-47, fig. 9). Among the Csokorgasse chickens three adult hens (41039/99, Figure 13.3A, 41316/97, Figure 13.6B and 41329/98) displayed a crooked keel. While the well preserved skeleton of 41316/97 does not show any other anomalies, the two other chicken skeletons show pathologies of their left ulna. In the case of 41039/99 an ulna fracture had healed under strong callous formation and the left femur shows something like an ossified sinew. The ulna of 41329/98 displays indentations of unknown origin, perhaps an infected bite. Given the fact that the skeleton adapts continuously to new circumstances, these pathologies in affected chickens could hint to the crooked keel being potentially caused by a malposition due to a painful pathology of the limbs.

13.4.2. Coxarthroses and femoral head necroses

Fourteen individuals, a remarkably high proportion of chicken skeletons in the Csokorgasse assemblage, show pathologies of the hip joint. Compared to the overall sex ratio the share of affected females is higher (5.5 hens to 1 rooster). Generally, these hip pathologies are accompanied by bone formations underneath the *caput femoris* and in the area of the *acetabulum pelvis*. The latter often shows a broadening of the acetabular rim. When only these signs appear on the respective bones, the hip afflictions can be interpreted as comparably light, yet certainly still painful (41065/99, Figure 13.3B; 41097/98, Figure 13.4A; 41217/95, Figure 13.5; 41369/96&99, 41381/97, 41390/98, 41514/98, 41548/97). The more severe cases display an already partially closed *acetabulum* and an affliction of the *caput femoris* (41373/98, 41451/97, Figure 13.7B; 41603/99, Figure 13.8B; 41616/98, Figure 13.9A). And the worst cases (41296/99, Figure 13.6A; 41397/98, Figure 13.7A) show a degenerated *caput femoris*, remains of which can be detached and fused to the pelvis.

Coxarthroses caused by an extensive abrasion of cartilage are frequently encountered in present-day broiler chickens that suffer from too rapid and intensive weight gain (Thorp 1994, 218-219). Other factors could be a malposition in consequence of other pathological conditions (these could be fractures: 41217/95, Figure 135; 41390/98, 41616/98, Figure 13.9A; or possibly infections: 41065/99, Figure 13.3B; 41097/98, Figure 13.4A; 41603/99, Figure 13.8B).

A necrosis of bone matter sets in when the bone is no longer supplied by blood vessels (Waldron 2009, 144). Clinical cases including necroses of the proximal femur today often occur in consequence of bacterial infections of the femoral cartilage (*chondritis*) or marrow (*osteomyelitis*). They can enter the affected area either by way of blood circulation or through an open wound. Typical pathogenes are *Staphylococcus* sp., *Escherichia coli* and *Salmonella* (Thorp 1994, 216-217). It was certainly an infection that caused the two severe cases 41296/99 (Figure 13.6A) and 41397/98 (Figure 13.7A).

Three chickens show nodules on their ribs. All animals with these rib nodules also show hip afflictions: two of them to a light degree (41065/99, 41097/98, Figure 13.4A) and another one (41603/99, Figure 13.8B) a medium degree. In mammals (including humans), comparable lumps are sometimes interpreted as potential signs for tuberculosis (Waldron 2009, 117). In premodern times, avian tuberculosis was a common disease in poultry stocks. It is caused by *Mycobacterium avium* which is also pathogenic for humans and other livestock. Even though it primarily affects the lungs, avian tuberculosis is known to affect the long bones of the bird leg, primarily the marrow. The skeletal alterations it causes, however, are described as smooth bulges on the diaphysis (Baker and Brothwell 1980, 77).

13.4.3 Thickening of the proximal end of the tarsometatarsus

Even though only two otherwise healthy individuals show a thickening in the proximal section of the left tarsometatarsus, a hen (41597/98, Figure 13.8A) and a rooster (41670/98&99, Figure 13.9B), this condition deserves to be discussed briefly. From both individuals only one tarsometatarsus is present. Hence, we do not know whether this alteration appeared symmetrically or only in one of the feet. The present condition resembles the so-called "twisted leg", perhaps a Valgus-Varus deformity of the intertarsal joint (Julian 1984, 254). In modern broiler chickens, these irregular angulations and enlargements of the intertarsal joint are likely due to malnutrition at a very early age and can be seen even in animals only some days old. However, *osteomyelitis* or *osteitis* cannot be ruled out either as a cause for these symptoms.

13.5 Conclusions

Animal bone materials from cemeteries present a high potential for palaeopathological studies because they offer the opportunity to analyse complete animal skeletons from closed find contexts. We have to bear in mind, however, that the selection of chickens for burial purposes might be skewed by cultural considerations. As these animals usually die young, very large assemblages are needed for palaeopathological analyses because only a small part of the skeletons shows pathological symptoms. Even though the Csokorgasse chicken bone material is vast by archaeozoological standards and the number of pathologically affected individuals impressive, reliable statistical analyses still cannot be carried out. The rich material, however, makes it visible that the sex ratio of chickens displaying pathological lesions is somewhat skewed: hens were more susceptible to disease than roosters. This may be due to intensive egg production which exerts a strong physical strain, or to more pathogenic keeping conditions for the hatching females.

Increasing data series will be necessary to obtain a more complete picture. However, the bone finds from the Avar cemetery at Vienna Csokorgasse represent an important first step towards a palaeopathological assessment of past chicken populations.

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14. "Babos" (Spotted) Pigs in Zalavár/ Mosaburg, SW Hungary: Possible Causes of a Tusk Pathology

Annamária Bárány

A relatively frequent boar-tusk deformation is observed in the animal bone material of the 9th-century-Carolingian Period settlement of Zalavár. These boars were once considered an independent breed unique to Zalavár. This theoretical breed could be the result of occasional interbreeding between domestic pigs and the local wild boar population. However, this particular deformation is identified in cases from other sites and present-day examples are also known, thus rather suggesting the prevalence of a pathological disorder. In this paper, the possible causes of the deformation are investigated.

14.1 Introduction

Mosaburg is a unique site in south-western Hungary, in the region of the Kis-Balaton marshland, located to the outskirts of the present-day settlement of Zalavár (Figure 14.1). It was inhabited from the Carolingian period through to the Late Middle Ages, and particularly thrived in the 9th century. In AD 840 the town became a spiritual as well as profane centre of the easternmost province of the Carolingian Empire (Szőke 2002, 90); the regal castle was built and three churches were raised during the following 15 years. Food supplies had to be provided for the numerous local population and the visiting pilgrims. Faunal remains representing large amounts of food waste were collected during excavations. Until now, approximately 60,000 pieces of animal bones have been processed, which is about one-quarter of the total excavated animal remains. The processing and excavation continue year by year. At the recent stage, our data show that most of the animal bone assemblages (89%) date to the Carolingian Period and a smaller percentage (11%) date to the 11th-century Árpád period (Bárány and Vörös 2014, 125). Some of the Carolinigan period features represent secondary deposits, containing bone assemblages deposited earlier and redistributed during the landscaping of the settlement.

The archaeozoological finds of the site are unique because occupation in the Carolingian Period of Zalavár was short, lasting only two to three generations. Additionally, as the eastern peripheral region of a western culture, Zalavár was a place where representatives from different human populations arrived and settled.

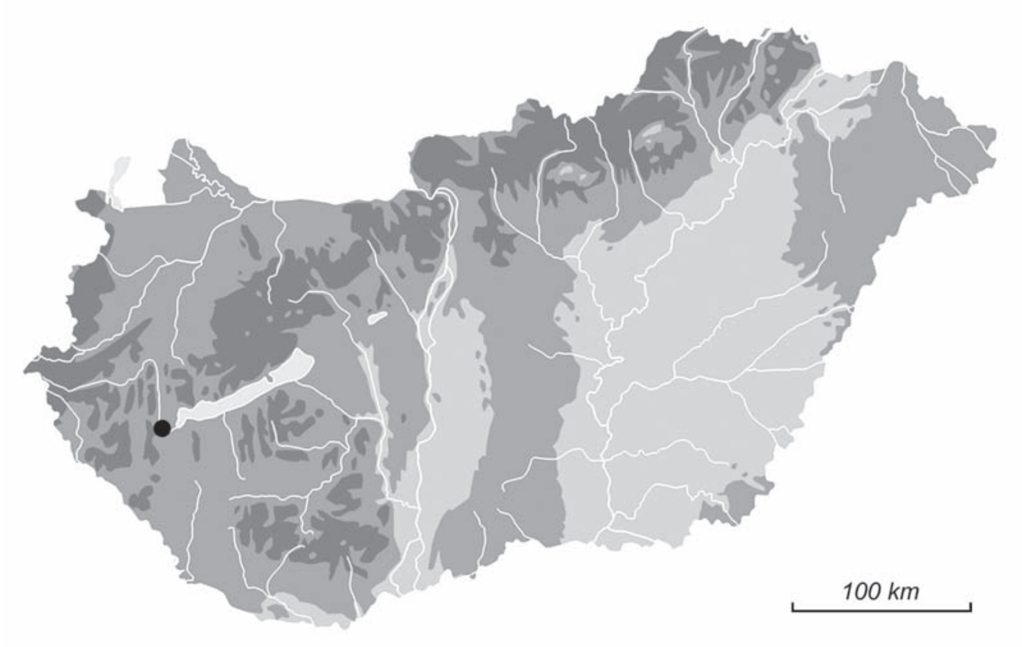

Figure 14.1. The location of Zalavár/Mosaburg site in present-day Hungary.

Bones from a total of 21 domestic and hunted animal species were found at the site of Zalavár/Mosaburg. Domestic animals represent the majority of identifiable specimens by number (93% NISP) and originate from eight mammalian species: cattle, sheep, goat, pig, horse, donkey, dog and cat. Hunted mammals include aurochs, red deer, roe deer, wild boar, fox, wolf, wild cat, lynx, *Martes* sp., badger, bear, beaver and hare, representing seven per cent of the total NISP (Bárány and Vörös 2014, 125). The representations of the species are shown in Figure 14.2.

14.2 Material and methods

Pig was the most frequently encountered species among the animal finds from Zalavár/Mosaburg accounting for just over half of all animal bone identifications (50.8%). The distribution of pig bones was broad; 98% of the revealed features contained pig remains. The majority of these (93%) represent body portions with the highest meat yields, such as the shoulder, upper legs and torso (Bárány and Vörös 2014, 126–127).

The land surrounding Zalavár/Mosaburg was ideal for pig keeping. In the 9th century, the marshy bay system of Kis-Balaton was integrally connected to Lake Balaton. Work to separate the bay from the main lake was completed by the beginning of the 19th century (Takács 1978, 7). The settlement has been surrounded by a swampy terrain with oscillating water levels. The worms, snails, vegetation and other foods present in the marshland habitat easily provided pigs with the nutrients and minerals they needed.

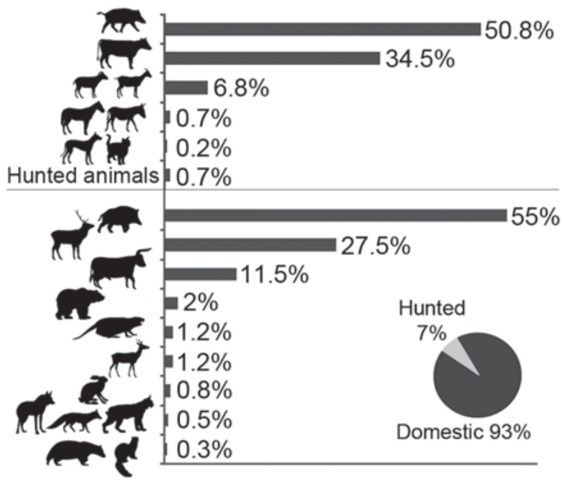

Figure 14.2. Distribution of the animal bones by quantity and species (%) from Zalavár/Mosaburg.

Moreover they offered wallowing places during the summer to make excess heat bearable. Pig keeping in the Kis-Balaton followed a continuous pattern well into the 18th–19th centuries (Szabadfalvi 1971, 329),where herds prowled the swamps and islands until autumn. In the autumn and often throughout the winter, pigs sustained themselves in acorn forests (Loyn and Percival 1975, 64–73). In Hungarian, two kinds of pig herds are distinguished by name: the term "*csürhe*" refers to animals returning to the house at the end of each day, while the term "*konda*" was used in reference to animals spending all, or part, of the year in the forests and meadows. Acorn-feeding was described in the *Capitulare de villis vel curtis imperii* (translation in Loyn and Percival 1975, 64–73), a property-husbandry manual on animal-keeping, written at the beginning of the 9th century, for officers of royal properties. It is probable that similar husbandry patterns were prescribed for Zalavár/Mosaburg. The following excerpts discuss pig keeping and handling:

> 23. On each of our estates the stewards are to have as many byres, pigsties, sheepfolds and goat-pens as possible, and under no circumstances are they to be without them (translation in Loyn and Percival 1975, 66).
> 36. [...]if they send their pigs into our woods to be fattened [...](translation in Loyn and Percival 1975, 67).

Evidence of epiphyseal fusion suggests pigs were characteristically slaughtered at Zalavár before reaching 2–3 years of age. Bone measurements from the fully processed data indicate calculated withers heights (Teichert 1969, 286) for the Zalavár pigs between 63 and 80 cm (average 74 cm, n=16) for sows and between 81 and 90 cm (average 85 cm, n=21) for boars (Bárány and Vörös 2014, 127). These values approach the average height of wild boars (93.3 cm for boars, 88.2 for sows; Faragó 2012, 454) but are smaller than the statures of modern pigs. Wild boars from Zalavár were large animals with withers heights ranging between 80 and 114 cm (average 101.9 cm, n=18) (Bárány and Vörös 2014, 127).

The aforementioned wild boar-size pig canines belonged to mandibles with greater corpus heights and occasionally showed a pathological abnormality on the corpus of the mandibles. A walnut-sized protrusion (*protuberantia*) was identified on the buccal surface of the mandibular body on some of the "tall" mandibles, usually in line with

Figure 14.3. Skull fragment of a domestic pig from Zalavár/Mosaburg (lateral view). Scale=3 cm.

the alveolar space between M_1 and M_2 (Figure 14.5). This appears to have been caused by the over-growth of the root of the lower canine (tusk). The root of the canine is deformed with transverse rings, turned on its side and creates space causing a protrusion on the buccal surface of the mandible. In extreme cases the end of the root breaks through the top of the protrusion, leading to the opening of a large fistula. In the living animal, it possibly perforated the inner mucosa of the buccal cavity, causing a clearly observable lesion on the outer surface of the snout.

This pathology is not observed on many mandibles (only 18 out

Figure 14.4. The two types of pig mandibles from Zalavár/ Mosaburg (lateral view). Scale=3 cm.

Figure 14.5. Domestic pig mandible with pathological disorder from Zalavár/Mosaburg (lateral, medial and dorsal view). Scale=3 cm.

of 374, *i.e.* 4.8%) at Zalavár/Mosaburg but occurs here much more frequently with much more pronounced cases than elsewhere. Only a few mandibles with the same deformation or alteration are known from other sites. One mandible was found at each of the following four sites: Neolithic Polgár-Csőszhalom (inventory number 6/463/936.1, ELTERI), Roman Period Sarmatian Tiszagyenda-Lakhatom (feature 2605/3829), Avar Period Kölked-Feketekapu "B" (house no. 111) and Early Modern Age Gyula-Vár (inventory number 61.22.2, MNM).

14.3 Results and discussion

The boars in question were once considered representatives of an independent breed (Bökönyi 1974, 223). However, the broad geographical and temporal distributions of occurrences suggest this could be a pathological disorder. But what could cause this kind of deformation? Could it be the result of hybridisation between the local domestic herd and wild boars? Even today, hybridisation is not uncommon (Faragó 2012, 462). The acorn feeding season overlaps with the breeding season, providing opportunity of crossbreeding between the wild and domestic forms.

In the early stages of domestication, alterations can often be detected on the mandible. "With shortening of the skull the changes on the mandible are characteristic, for they became shortened to such an extent that the teeth which became shorter only at a later stage, had no room in the alveolus. Thus the first premolar was missing from practically every mandible. Nor was there any room for the big canines of the boars" (Bökönyi 1974, 223). Hybridisation could be characterised as a reverse domestication, where wild phenotypic traits are rapidly reintroduced. For example, reconstructions of "Iron Age pigs", which are the result of crossbreeding between Tamworth sows and wild boars, show frequent manifestations of wild phenotypic traits in the descendants. Hybridisation affects the traits of wild pigs as well. A rapid size reduction could be detected even in the first generation: muscle insertion surfaces became smoother and the bones thicker (Matolcsi 1975, 97). Changes in the

Figure 14.6. Mandible of Sus scrofa papuensis *from the Mammal Collection of the Hungarian Natural History Museum (dorsal view). Scale=3 cm.*

oestrus cycle, increases in litter size, reduction of brain volume and the appearance of spotted (“babos”) individuals are also the result of hybridisation (Faragó 2012, 462). Modern phenotypic variability in pigs is represented by the numerous breeds from around the world.

In addition to hereditary traits, environmental circumstances also affect the phenotype of animals: the shortening of the skull can result from accelerated growth under good keeping conditions, while rougher circumstances can cause elongated, flatter, “wild-type” skulls among individuals from the same litter (Brehm n.d., 150).

Wild Suidae specimens were analysed in the Mammal Collection of the Hungarian Natural History Museum in order to investigate possible causes of this pathology. Among these specimens, neither the Buru babirusa (*Babyrousa babyrussa*) nor the giant forest hog (*Hylochoerus meinertzhageni*), nor the warthog (*Phacochoreus aethiopicus*) with naturally occurring large canines, were identified showing the pathological lesion under discussion here. One Papuan wild pig (*Sus scrofa papuensis)*, developed the same protuberance on its mandible (Figure 14.6). This pathology could be found within the domestic pig population from the same region. On the islands of the New Hebrides (Republic of Vanuatu), pigs are highly respected and sacred breeds were developed and maintained for cultural purposes. People from the north and central islands created “tusker” pigs that were imbued with spiritual significance and required for traditional chiefly rank taking, so called *Nimangki* (Lum *et al*. 2006, 171–191). Their spirally twisted canines are even displayed in the local flag (Figure 14.7) and still serve

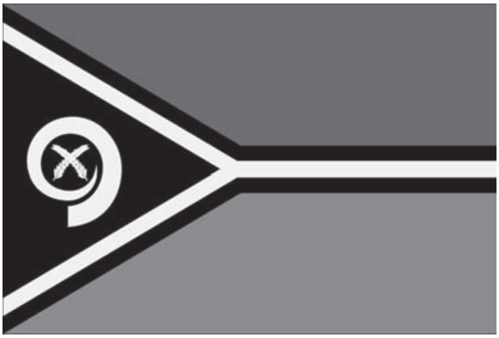

Figure 14.7. The flag of the Republic of Vanuatu.

as means of payment. This spiral twist in the tusk is a result of human intervention. Boar tusks normally grow continuously but are sharpened, and abraded, through contact with the opposing upper canines. "Avulsion of the upper canines allows the tusks to circularize, completing a full rotation in 6–7 years and a double circle in 10–12 years[...] Tusker boars were often traditionally castrated to reduce their aggression, facilitate their care, and reduce the risks of fights and broken tusks" (Lum *et al*. 2006, 171–191). In addition to the normal tuskers, there are special *Narave* tuskers, intersex male boars with variable testis development, hormone production, and spermatogenesis (Lum *et al*. 2006, 171–191). The mandibles of these tuskers display the same tuber or fracture in the line of the M_1–M_2,as observed in the pigs from Zalavár/Mosaburg. Certainly, this does not suggest the pathologies observed in Hungarian pigs share the same origin as those from Vanuatu. However, the fact that overgrowth of the lower tusk can cause such an alternation is supported by a chance encounter with another specimen in the Mammal Collection at the Hungarian Natural History Museum (inventory number 2015.5.1). This European wild boar had an asymmetric lower jaw, where a projecting tuber was observed on the left side, but not on the right (Figure 14.8, pathology indicated by arrow). This specimen was named the No. 1 boar tusk of the Safari Club International (SCI) in 2012 indicating its spectacular dimensions. Its lower canines measured 43.9 cm in length on the left side and 22.7 cm on the right side. This asymmetry was caused by a missing upper left canine, allowing the lower canine to grow without limitation. According to the documentation, this individual was 7 years old and undernourished, possibly a result of feeding problems associated with an overgrown tusk.

As previously mentioned, male wild boars have continuously growing (hypselodont) upper and lower canines. This type of tooth has an open root which, in the case of the boar's lower canine, ends at the border of the P_4 and M_1 teeth. It is believed that continuously growing tusks have developed as a response to increased stress derived from interspecific and intraspecific conflicts and foraging activity (*i. e.* rooting, stone-lifting). Wild pigs also use their tusks to peel off the bark from pine trees in order to gain resin, which hardens after being spread onto the fur over the scapular region, creating so called "shields" (Faragó 2012, 458), which protect the animal from injuries. Ideal tusk size is maintained by the continuous and reciprocal attrition of the opposing tusk-pairs (Figure 14.9).

Continuous growth of the tooth relies on epithelial and mesenchymal stem cells that give rise to the different cell lineages of the tooth (Renvoisè and Michon 2014, 5). These stem cells are located at the base of the tooth in a structure called the cervical loop (Harada *et al*. 1999, 106). In the case of continuously growing rodent incisors, researchers found that "when renewal tissue is damaged by injury, adult stem cells appear to actively divide,

and further amplification of the daughter cells produces enormous numbers of differentiated cells that replenish the deficiency [...] expedit[ing] the repair of the tissue" (Harada *et al*. 2002, 2). Teeth with roots are supported in the bone by an attachment apparatus, known as the *periodontium*, which contains fibres that run from the cementum to the gingiva and the adjacent cortex of the alveolar bone. These fibres convert the compressive force weighed on the tooth into stimulating pulling force and send signals to the brain about the amount of pressure being endured. It is hypothesised in cases of hypselodonty "that physical forces of occlusion, dependent on the animal diet, its volume, soil grit and/or tooth attrition, might have mechanical effect on the tooth, and in turn, affects the stem cell niche, through a feedback loop pathway" (Renvoise and Michon 2014, 7). It is hypothesised here that the lack of attrition normally caused by continuous pressure from the opposing upper canine allowed these adult stem cells to "overproduce" leading to overgrow that both ends of the tusk.

Figure 14.8. Skull and mandible of the asymmetric specimen from the Mammal Collection of the Hungarian Natural History Museum (skull ventral view, mandible dorsal and lateral view). Scale=3 cm.

14.4 Conclusions

The basic question in this paper was: could this tusk-deformation, believed to be typical of the archaeological material from Zalavár/Mosaburg, be a result of the hybridisation between domestic pigs and wild boars or the sign of an early phase of domestication (caused by occasional back-crossing)? Examples from Vanuatu pig and the specimen from the Hungarian Natural History Museum indicate the deformation itself can be formed in the absence of the corresponding upper tusk. In this case another question arises: was it a natural process or human intervention that caused the removal of the upper tusk and in the latter case, why? It is known from ethnographic sources, that tusks were broken

Figure 14.9. The ideal match between the opposing tusk pairs in boar (dorsal view). Scale=3 cm.

to limit the animals' ability to demolish the sty (Szabadfalvi 2001, 769). This might have been the case in 9th-century Zalavár/Mosaburg. The large amount of recovered pig bones makes it difficult to identify matching pairs of maxillae and mandibles. However, no maxilla with broken out or removed tusks were identified at the site. Another modern example, Vietnamese pot-bellied pigs, highlights how mandibular deformation can form naturally as a result of poorly fitting upper and lower tusk pairs (Tynes 1999, 206).

Although the discussion mostly revolves around analogies, the pigs from Zalavár/Mosaburg may originate from two different groups based on variability in the height of the *corpus mandibulae*. Despite the fact that hybridisation is not the only cause of this deformation, the possibility of the crossbreeding remains. This could be investigated via geometric morphometrics involving the shape of the 2nd and 3rd molars (Evin *et al*. 2013, 736) or using genetic analyses based on the occurrence of the alleles of melanocortin-1 receptor (MC1R) gene (Koutsogiannouli *et al*. 2010, 69).

Acknowledgements

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15. Damage Caused by Permanent Fetters in Present-Day Sheep on the Island of Delos (Greece)

Yves Darton and Isabelle Rodet-Belarbi

Some sheep (*Ovis aries* Linnaeus, 1758) grazing on the island of Delos (Cyclades, Greece) wear fetters tying their front and hind limbs on one side. Through the study of skeletal remains, we observed various lesions they caused: greenstick subperiosteal fracture, enthesopathy of the posterior tendinous groove, lateral ligamentous ossification of the overlying tarsometatarsal joint by severe sprain, subperiosteal ossification (periostosis), luxuriant periostitis and localised, sometimes deep bone necrosis. Other animals displaying damage due to fetters are mentioned for comparison. The detection of fettering on bones is important in determining whether sheep are unattended or domestic, and in understanding the practices, sometimes cruel, to tend domestic animals.

15.1 Introduction

Since its foundation in 1846, the French School at Athens has directed archaeological expeditions in Greece. In coordination with the Greek government since 1873, it has been involved in excavations and the conservation of the cultural treasures on Delos, a small rocky island in the Cyclades with a surface area of 350.64 hectares in the heart of the Aegean Sea.

In this context, during a mission in August 2016 conducted by Professor Alain Bouet (Ausionus, University of Bordeaux, France), we observed sheep (*Ovis aries* Linnaeus, 1758) living in a small unattended herd; we did not approach them since they are fearful and unaccustomed to human presence. Although the entire island is a protected archaeological site, it remains public land belonging to the neighbouring island of Mykonos and only grazing is allowed there (Brunet, 1990). In early spring, shepherds from Mykonos transport their sheep on boats to Delos, where they graze until early summer before being returned to Mykonos. Over this period, they roam freely on the island, which features only an archaeological site and housing for museum staff and archaeologists working at the site. Given their gregarious nature, some sheep are fettered to facilitate bringing together the animals for the return trip. It may happen, however, that the entire herd is not gathered and a few individuals are left behind on the island of Delos.

15.2 Material and methods

We observed that the fetters, tied around the distal third of the metapodium, connect a front leg with a hind leg on either the right or left side of the animal (Figure 15.1.1–2). In some cases, the fetter is very short and considerably restricts the animal's movement, which can impede its ability to traverse the island's rugged topography. In the most extreme cases, this may lead to the animal's death, either because the fetter becomes entangled with a dead branch (Figure 15.1.3) or because it is caught in a stone wall as the animal tries to cross, and is left hanging by its leg (Figure 15.1.4). We discovered and collected several other animal skeletons with metacarpal and metatarsal bones still tied together by fetters. We conducted morphological studies, photographed, and scanned eight such specimens to characterize the range of possible lesions associated with such fetter use.

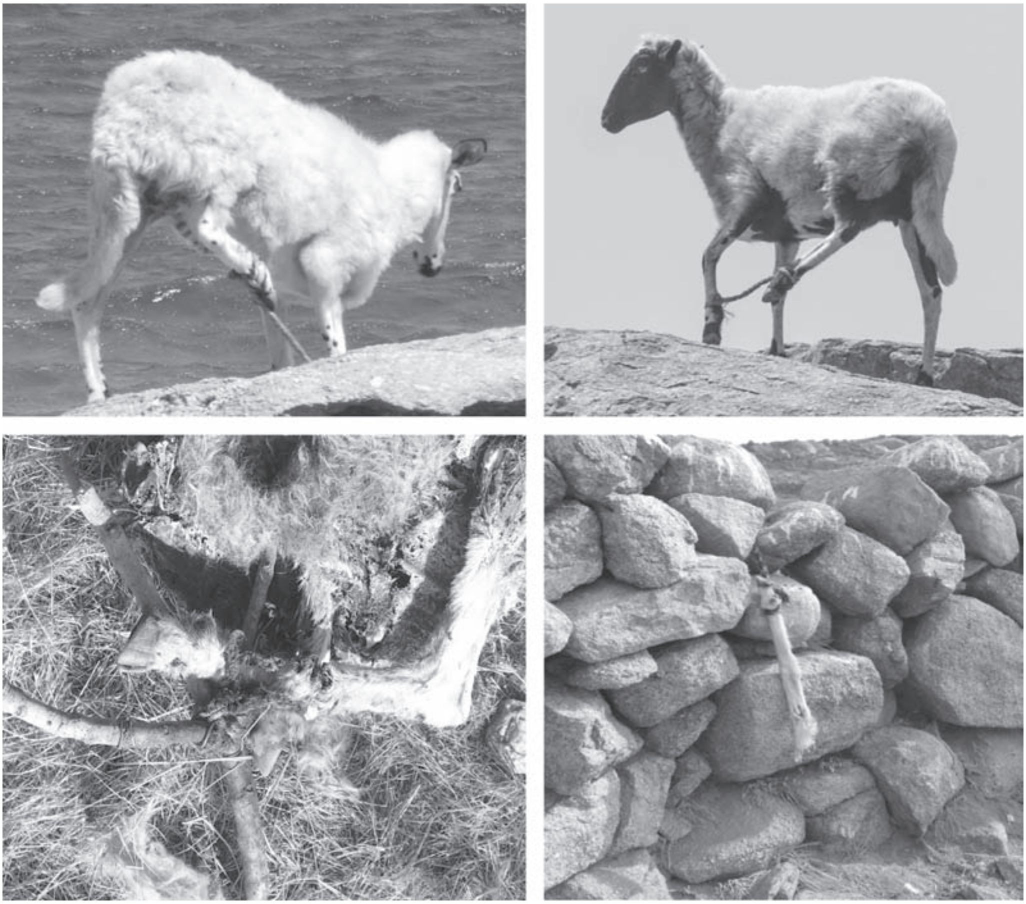

Figure 15.1. 1: Fettered ewe on the island of Delos (photo: E. Fournié); 2: Fettered ewe on the island of Delos (photo: P. Mora); 3: Dead branch entangled in a fetter (photo: I. Rodet-Belarbi); 4 Fetter caught between two stones in a wall (Photo: E. Fournié).

15.3 Results

The fetters are made using strands of plant fibre twisted with nylon thread, and attached to the sheep's legs using slipknots. For the five examples we were able to measure, the length of rope between the legs was variable, with values of 17 cm, 26 cm, 35 cm, 39 cm and 40 cm.

The sample of metacarpus and metatarsus bones studied revealed lesions with varying degrees of severity. We observed a range of conditions, including a greenstick subperiosteal fracture (case 1), enthesopathy of the plantar metatarsal tendinous groove of the digital flexor muscles (cases 2 and 3), lateral ligamentous ossification of the overlying tarsometatarsal joint (case 3), simple subperiosteal ossifications (case 4) or those with periostitis (case 5), and finally luxuriant periostitis, both without osteonecrosis (case 6) or with osteonecrosis (cases 7 and 8).

15.4 Discussion

The material used to make the fetters probably plays a major role in causing the lesions observed. The synthetic fibres included in their composition are very strong, and therefore have a severe impact on the animal. Furthermore, slipknots tighten around the legs and the rope is often short, such that each movement exerts great pressure on the skin, the underlying soft tissue, and bone. The lesions observed correspond to two pathophysiological processes that may be associated with each other. First, fetters may disrupt the biomechanics of the gait. Thus, the skewed axis of the distal third of the right metacarpus (case 1) indicates a consolidated subperiosteal greenstick fracture that occurred at the end of the animal's growth, at the position where the fetter created an abnormal fulcrum (Figure 15.2.1). Second, enthesopathy of the fibrous sheath of the digital flexor muscles (*m. flexor digitorum superficialis; m. flexor digitorum profundus*) at the metatarsus was observed on both the right and the left sides (cases 2 and 3). This is similar to the ossification often observed in the insertions of the digital flexor tendon fibrous sheaths in human manual workers. These features attest to a disrupted course of the tendon in its groove with excessive tension of the tendon sheath (Figures 15.2.2 and 15.2.3). Finally, lateral ligamentous ossification of the left overlying tarsometatarsal joint indicates a severe sprain (case 3).

Other lesions correspond to direct impingement caused by the fetters: subperiosteal ossification is linked to repeated contusion of soft tissue under the shackle, causing localized inflammation. This is an osteogenic reaction in the hyperhaemiated periosteum, not necessarily involving a subperiosteal haematoma which may undergo secondary ossification. Similar pathophysiological processes have been reported in the archaeological litetature, including a horse metacarpus discovered in 16th-century strata at Szentkirály and a sheep metatarsus from Roman Period strata at Dunaújváros-Intercisa (Hungary; Bartosiewicz 2013, 149, fig. 126A–B). Subperiosteal ossification may take the form of a simple isolated plaque on the right metatarsus, well incorporated in the diaphyseal cortex (case 4; Figure 15.2.4), or as similar plaque under a layer of periostitis on a right metatarsus, less compact in structure, indicating the irruption of an infectious element due to an associated skin lesion (case 5; Figure 15.2.5). Similarly, the exuberant

Figure 15.2. 1: Right metacarpus; 2: Right metatarsus; 3: Left metatarsus; 4: Right metatarsus; 5: Right metatarsus; 6: Right metatarsus (Photos: J. D. Strich CEPAM, CNRS).

sheathing hyperostosis developing on either side of the area of impingement between the fetter and the bone (right metatarsus) implies a factor promoting the diffusion of bone production (case 6; Figure 15.2.6). Chronic infection due to skin effraction seems most likely, in which case ossification would correspond to bony metaplasia of the connective tissue caused by inflammation. The folds visible on the bone surface underscore the path to septic inflammation in the surrounding tissue. A Neolithic cattle metatarsus, from Polyanitsa, Bulgaria, reveals a comparable aspect, which may have had the same cause (Bartosiewicz 2013, 93, fig. 71). The final stage of bone damage is ischemic necrosis, which first caused the periosteum to disappear in the area of friction with the fetter, leaving the bone bare. Vascularisation of the periosteum is fragile in sheep metapodia, as a longitudinal dorsal artery runs between the fibrous layer and the osteogenic layer, supplying an annular system of transversal circular ramifications

Figure 15.3. Right metacarpus and metatarsus (Photos: J. D. Strich CEPAM, CNRS).

Figure 15.4. Right metacarpus (Photos: J. D. Strich CEPAM, CNRS).

with little communication (Simpson 1985). When it undergoes local destruction due to ischemic necrosis (case 7; right metacarpus; Figure 15.3), it loses its protective utility for bone, leaving it exposed to direct constraint from lateral pressure. In this situation, bone is left with little adaptive ability. Mechanical wear on bone, which includes ischemia of the osteons which hinders bone remodelling (de Vernejoul and Marie 1993), leads to gradual bone loss (case 7; right metatarsus; fig. 3, and case 8; right metacarpus; Figure 15.4). After generating a few endosteal ossification plaques insufficient to avert the destructive alteration, the endosteum underwent the same process (Figure 15.5).

We found other examples of animals suffering from damage caused by fetters. We were able to study the skeleton of a Canada goose (*Branta canadensis* Linnaeus, 1758) in the comparative anatomy collections at the National Museum of Natural History in Paris (no. 1996-52), which was certainly tied with a cord attached to its leg. The lesions on its right tarsometatarsus correspond to circular disruption of bone remodelling, accompanied by exuberant sheathing hyperostosis developing on either side of the area of impingement between the bond and the bone (Figure 15.6).

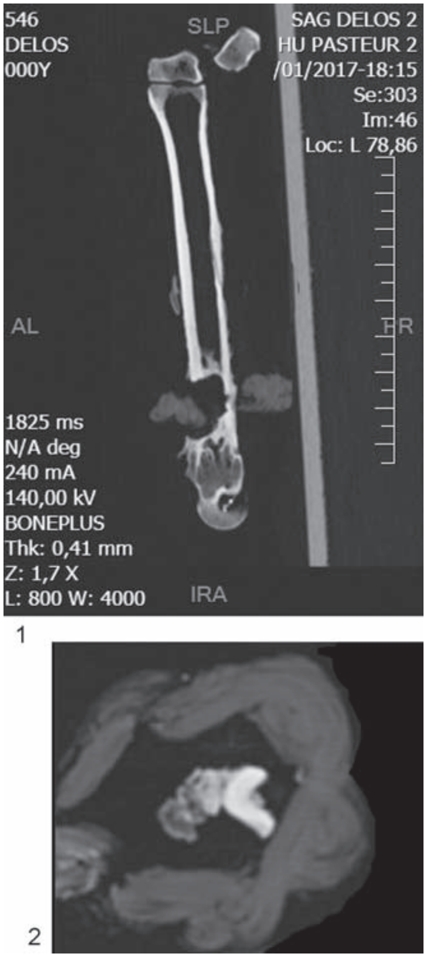

Figure 15.5. Scanned right metacarpus (Photos: CHU Hôpital Pasteur, Nice).

So far, we have observed no compelling examples of damage caused by fetters in sheep metapodia found in an archaeological context. Certain diaphyseal deformations, however, provide a candidate for fetter-related pathology. The case of a metapodium from a small ruminant found in an excavation on Place des Célestins in Lyon (Rhône; 7th–11th century; Forest 1987), which displayed diaphyseal stenosis, could have resulted from similar bonds (Etier-Lafon 1997, 85). The same can be said for a metatarsus discovered in the mediaeval site of Lastours (Aude; 13th–14th century; Etier-Lafon 1997, 85).

The damage caused to animal legs by fetters can be compared to a deformed horse mandible found in the site of Polgár–Kenderföld (Hungary; Middle Bronze Age) displaying deficient bone remodelling directly linked to a rope bridle placed around the region of the diastema, as is still practised in Ethiopia (Bartosiewicz 2013, 134–135, figs 111–112).

The effects of rope fetters on animal bone are a sad reality. It is important to investigate them in the archaeological record. They are interesting clues to understand some animal management strategies.

Figure 15.6. Tarsometatarsus from a Canada goose (MNHN no. 1996-52; Photo: I. Rodet-Belarbi).

15.5 Conclusions

The bone lesions we were able to directly attribute to fettering in our series correspond to various coherent pathophysiological processes, subperiosteal greenstick fracture, enthesopathy of the posterior tendinous groove, lateral ligamentous ossification of the overlying tarsometatarsal joint by severe sprain, subperiosteal ossification (periostosis), luxuriant periostitis and localised, sometimes deep bone necrosis. These lesions may be isolated or follow in succession. The information we obtained may be useful in identifying shackles or fettering practices among archaeological specimens, even in the absence of direct material evidence for such bonds. The detection of fettering on bones is important in determining whether sheep are unattended or domestic, and in understanding traditional practices, sometimes cruel, in tending domestic animals.

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16. Medieval Multi-Horned Sheep from Present-Day Budapest, Hungary

Márta Daróczi-Szabó and László Daróczi-Szabó

Polyceraty is an inherited cranial anomaly in domestic bovids. Approximately two dozen archaeological sites in Europe are known to have yielded multi-horned sheep crania in medieval Europe. In addition to a previous find from the Buda Castle (Budapest, Hungary) reported in 1977, two more cranial remains of this kind have been discovered in the same area during the last twenty years. A fourth piece came from the Hajógyári Island also located within the municipal area of present-day Budapest. The aim of this paper is to provide an overview of these rare finds.

16.1 Introduction

Inherited factors cause a number of disorders in the skeletal system of domesticates. Many of them are caused by inbreeding, or occur as side effects of selection for a particular desirable trait (Bartosiewicz 2013). While many inherited disorders are truly pathological, a small group of non-lethal anomalies also produced by anthropogenic selection result animals valued primarily for their curious appearance.

The existence of multi-horned sheep in antiquity is known from various sources in Ancient Egypt. Rams with spiral-shaped, straight horns and smaller, curved side-horns are depicted on a Ptolemaic Period (305–30 BC) limestone votive probably from Quena, Egypt (Houlihan 1996, 23, fig. 17). Claudius Aelianus (AD 175–*ca*. 235) writes a in his book *De Natura Animalium* (Book XI 40): "*Oves etiam tum quadricornes, tum tricornes, fuerunt in templo Jovis custodis urbis* [*in Aegypto*]" ("Moreover there were even Sheep with four horns and with three horns in the temple of Zeus, the Guardian of the City"; translated by Alwyn Faber Scholfield 1958, 412).

This paper explores rare archaeological finds of multi-horned sheep from central Europe. Limiting our consideration to only those specimens from late medieval (14th–15th-century) contexts (*e.g.* Müller 1981; Putelat 2005, 298, fig. 9; 2006; Wigh 2001, 92, fig. 51; Maldre 2008, 293, fig. 17) the absolute number of such specimens is quite rare, although 60% of the known archaeological sites that yielded multi-horned sheep postdate the 11th century (Bartosiewicz 2013, 190, fig. 162). During the course of the last twenty years of archaeozoological research, fragmented skulls of three multi-horned sheep were recovered from the area of modern Budapest by archaeologists of the Budapest History Museum. These, together with the fragment previously described by János Matolcsi (see below), increase the number of such finds from the territory of Budapest to four (Figure 16.1). István Vörös (2000, 91) also described a multi-horned goat find from the 11–13th-century rural site of Szarvas-Rózsás, located in south-eastern

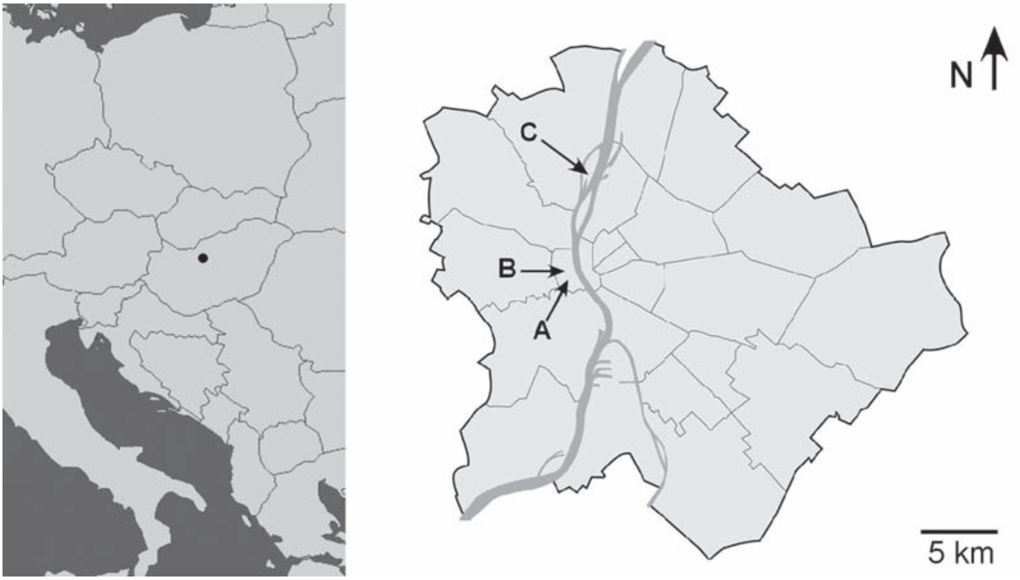

Figure 16.1. Location of Budapest in east Central Europe (left) and the sites discussed in the paper in relation to present-day Budapest (right). A: Buda Castle, Royal Palace Northern Forecourt; B: Buda Castle, Szent György Square; C: Hajógyári Island.

Hungary. These curious specimens from Budapest were previously summarised by Bartosiewicz (2013, 187–191). Here, we provide a detailed description of the finds along with their archaeological context.

16.2 Material

16.2.1 Royal Palace Northern Forecourt (Figures 16.1A and 16.7A)

The first known four-horned sheep skull came to light from the Northern Forecourt in the Royal Palace (Buda Castle), during the course of excavations between 1967–1975. The animal remains were analysed by János Matolcsi (1977). Since the authors of this paper were unable to relocate this skull, the multi-horned sheep is known only by Matolcsi's original description: "... *négy szarvú fiatal bárányt, amelynek homlokcsontja és falcsontja került elő s az utóbbin jól látható a négy, mintegy másfél-két cm hosszú kis szarvcsap-kezdemény*." ("... a four-horned young lamb, whose frontal and parietal bones were found, and the latter [sic] clearly shows four, roughly 1.5–2 cm long, small horn cores"; translated by László Daróczi-Szabó). The find was dated to the 14th–15th century (Matolcsi 1977, 183, Photo 224).

16.2.2 No. 4–10 Szent György Square (Figures 16.1B and 16.7B)

Excavations in 1998 directed by András Végh (Végh 2003) uncovered another find dated to the 14th–15th century, in Well 85 at the site of No. 4–10 Szent György Square in

the Buda Castle area. The specimen consists of a left-side frontal bone fragment with two horn cores bent away from each other (Figure 16.2). At the end of the caudally-located, smaller horn core, we observed a fissure approximately 1 cm in length (marked in Figure 16.2). The edges of this lesion appear natural, rather than anthropogenic or taphonomic (*e.g.* cut marks or post-depositional damage). The relatively small size of horn cores might be explained by the age (the fragment may originate from a subadult sheep), or the sex of the animal (remains of a female individual). Unfortunately, the fragmented state of the find precludes precise determination of age and sex. Similarly, due to fragmentation it cannot be determined how many horns were originally present (*i.e.* whether the double horn on the preserved left side had a symmetric counterpart on the right). Multi-horned sheep may develop horns in asymmetrical fashion: sometimes growing three or even five horns (Gáspárdy 2002, 70). Nonetheless, this specimen appears to have had more than two horns.

Figure 16.2. Multi-horned sheep frontal bone fragment (A) from Well 85 at Szent György Square (left side, lateral view). Scale=5 cm.

16.2.3 Szent György Square (Figures 16.1B and 16.7B)

The skull, which has survived in good condition, also came from the 1998–2000 Szent György Square excavations. Unfortunately, however, associated archaeological data pertaining to its excavation have been lost. Two of the horns from this subadult ram are bent upwards and then slightly aborally. Two additional, smaller horn cores are

Figure 16.3. Multi-horned sheep skull (B) from Szent György Square (frontal view). Scale=5 cm.

Figure 16.4. Multi-horned sheep skull (B) from Szent György Square (caudal view). Scale=5 cm.

Figure 16.5. Multi-horned sheep skull (B) from Szent György Square (lateral view). Scale=5 cm.

bent laterally and point downwards. There are several heavy chop marks on the forehead and nape of this skull. On the frontal bone, chop marks are observable above the orbit and under the base of the two upper horns. The skull is broken close to the left orbit, likely due to the force and number of the blows (Figure 16.3). Another heavy chop mark is visible at the base of the lower left horn. The cut marks noted on the occipital part between the horns, on the lower left, and the base of the upper left horn are shallower (Figure 16.4). These cutmarks suggest the possibility that someone wanted to keep the unusual-looking horns as a sort of a trophy. However, even if this was the aim, the method of attempted separation was crude and ultimately unsuccessful. Traces of burning were also noted on the lower right horn core, although it cannot be determined whether they are contemporaneous or the result of subsequent, secondary burning (Figure 16.5).

16.2.4 Hajógyári Island (Figure 16.1C)

A right-side frontal bone fragment with two parallel horn cores, dated to the 14th–15th century was found on the Hajógyári Island in 2009 excavated by Zoltán Havas and Anikó Tóth (Havas and Tóth 2010). Although the upright position of the horn cores appears goat-like, their shape is diagnostic of sheep (Figure 16.6). The horn core of this specimen is strongly reminiscent of a similar specimen recovered in 12th-century Mecklenburg (Müller 1981, Abb. 2). In the case of such remains, it is hard to decide whether the live animal had two separate horns, or if instead the fissure between these two horn-cores was hidden, providing the basis for a single, wide horn. Measurements on the three cranial fragments available for study were taken according to the protocol compiled by Angela von den Driesch (1976, 31–34) and are summarised in Table 16.1.

16.3 Discussion and hypotheses

Although one of the four multi-horned sheep skulls was unavailable for dating, it is remarkable that each of the other multi-horned sheep specimens known from Hungary dates to the 14th–15th century. Moreover, three such animals appear in close proximity to the Royal Palace in the Buda Castle (Figure 16.7). The first royal residence on the Castle Hill of Buda was built in the mid-13th century, just north of this area. Construction of a new palace in the previously uninhabited southern section of the hill began in the 14th century and lasted until the 1420s (Bartosiewicz 2001, 37). Datable finds of four-horned sheep coincide with this prosperous time period. The fourth specimen, recovered from Hajógyári Island, is also located relatively close (*ca.* 8 km) to the Buda Castle. Assuming a genetic basis for this mutation, it is possible that the analysed individuals from the same historical period were in fact related.

To some extent, this apparent concentration of multi-horned sheep may be an artefact of unusually intensive excavations in the Buda Castle district: large animal bone assemblages tend to yield any type of rare finds with greater statistical probability. Nonetheless, earlier and later archaeological periods at the same location have also been sampled intensively, yet have not revealed evidence of four-horned sheep.

Although there are no known medieval written descriptions of multi-horned sheep in Hungary, in the late 17th century Daniel Speer (1683, 179) wrote the following about sheep in the Carpathian Basin: "*Ihre 2. 4. und 6. hoͤrnichte Schaff oder Widder seynd noch einmal so groß, als die Schaff im Wuertemberger Land*" ("Their two, four or six-horned sheep or rams are twice as large as the sheep in Württemberg Land"; translated by László

Figure 16.6. Multi-horned sheep skull fragment (C) from Hajógyári Island (right side, lateral view). Scale=5 cm.

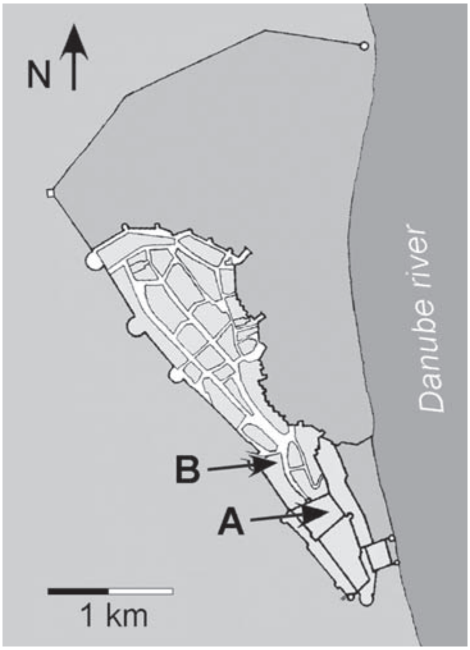

Figure 16.7. The two sites in Buda Castle. A: Royal Palace Northern Forecourt, B: Szent György Square.

Table 16.1.Cranial measurements (mm) of the specimens presented in this study according to von den Driesch (1976). Estimates are marked by asterisks.

Measurements	*No. 4–10 Szent György Square*	*Szent György Square No date*	*Hajógyári Island*
14. Greatest length of the lacrimal		38.4	
23. Length of the premolar row		26.6	
24. Greatest inner length of the orbit: Ectorbitale-Entorbitale		39.6	
25. Greatest inner height of the orbit		38.0	
31. Least breadth of parietal		40.2	
33. Greatest neurocranium breadth: Euryon-Euryon		62.0	
35. Least breadth between the orbits: Entorbitale–Entorbitale		70.3	
36. Facial breadth: breadth across the facial tuberosities		67.8	
38. Greatest breadth across the premaxillae		37.4	
39. Greatest palatal breadth		63.1	
41. Greatest (oro-aboral) diameter of the right-under horn core base		33.3	18.0*
42. Least (latero-medial) diameter of the right-under horn core base		26.5	
43. Length of the right-under horncore on the front margin		*>80.0*	58.0
41. Greatest (oro-aboral) diameter of the right-upper horn core base		47.1	14.0*
42. Least (latero-medial) diameter of the right-upper horn core base		38.1	
43. Length of the right-upper horncore on the front margin		148.0	69.2
41. Greatest (oro-aboral) diameter of the left-under horn core base	29.7	45.6	
42. Least (latero-medial) diameter of the left-under horn core base	22.3	37.2	
43. Length of the left-under horncore on the front margin	49.0	118.0	
41. Greatest (oro-aboral) diameter of the left-upper horn core base	25.5	35.5	
42. Least (latero-medial) diameter of the left-upper horn core base	18.7	28.5	
43. Length of the left-upper horncore on the front margin	44.0	123.0*	

Bartosiewicz). The reference to the large size of these sheep seems to indicate that some status was attached to owning such spectacular animals, as has been documented with long-horned cattle during the Early Modern Age (Alderson 1989, 60).

The observation by Daniel Speer clearly proves that multi-horned sheep existed in Hungary, some three centuries after the finds discussed here, although his description suggests that they may have been a curiosity to those from the Duchy of Württemberg, located in southern Germany. Speer's comparison with sheep in Württemberg, is also noteworthy, as other medieval archaeological finds of multi-horned sheep have so far been concentrated in the Western Baltic area. Linné (1732 [1811], 51) observed that in Scania, the southernmost section of the Scandinavian Peninsula, some rams had four, six or even eight horns. Johann Wilhelm David Korth (1825, 21–22) writes about Danish sheep: "*Die Widder sind gewöhnlich zwei- oder vierhörnig, die Hörner sind nicht so stark geriffelt und gewunden als bei den Spanischen*" ("The rams are usually two- or four-horned, the horns are not so strongly ribbed and twisted as in the Spanish [sheep]", translated by László Bartosiewicz). These texts raise questions about the origins and breeding history of multi-horned sheep in Hungary, and whether they relate to those known from other regions.

Horn inheritance in sheep is notoriously complicated, exceeding the complexities observed in cattle (Hámori 197). The simple presence or absence of horns is thought to be controlled by a single pair of genes. The lack of horns is presumably a dominant trait, while polyceraty is supposedly dominant over the "usual" two horns (Watson 1978). Watson (1978) asserted that the allele for four horns is a dominant trait, while Henson (1981) argued that the two-horned allele is dominant over the allele for four horns. Empirical observations, however, tend to contradict these simple hypotheses, as the expected patterns of dominant/recessive inheritance cannot always be reproduced by various crossing experiments (Alderson 1989, 59). Medway (2011) summarises these contradicting views regarding the inheritance of polyceraty, pointing out the complex nature of this problem. Consequently, in the absence of other lines of evidence (such as ancient DNA), the presence of multi-horned sheep cannot easily be used to infer patterns of breeding or ancestry in the archaeological record.

In present-day multiple horned sheep breeds (Hebridean, Jacob and Manx) polyceraty is associated with the inheritance of split upper eyelids, a pathological condition of considerable welfare implications (Medway 2011). While this disease itself cannot be traced in cranial morphology, it illustrates the thin line between harmless anomalies and truely pathological conditions.

16.4 Conclusions

Archaeological remains of multi-horned sheep are rare in Europe, although they are encountered more commonly at medieval excavations. Our identification of a cluster of 14th–15th-century four-horned sheep skull fragments (and one undated specimen) within the area of present-day Budapest is therefore surprising, and could reflect association of this trait with medieval sheep breeding practices in the region. Due to their occurrence in high-status sections of the medieval city, and chop marks suggesting that (at least in one case) the large horns were seen as a potential trophy, it may be

hypothesised that these animals were highly prized. Research into the genetic aspects of polyceraty inheritance will help further elucidate the roles these animals played in late medieval culture.

Note

1 After the manuscript submission deadline, a 14th–15th century multi-horned sheep skull fragment was found at Budapest–Fő utca 2, between the eastern wall of the Buda Castle and the Danube, ca 200–250 m from Szent György square (excavator: Judit Benda). It will be detailed in a future study.

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17. Weird Fish: Defining a Role for Fish Palaeopathology

Jennifer Harland and Wim Van Neer

The study of animal palaeopathology is a maturing subset of zooarchaeology. However, fish bone pathologies have rarely been discussed in any detail; even within modern fisheries literature bone pathologies from wild taxa are rarely mentioned. This paper uses several large assemblages from the North Atlantic region, as well as a single freshwater example from Belgium, to provide the first categorisation of fish pathologies. Six types of abnormality have been identified: injuries, tooth "abscesses", age-related joint disease, congenital abnormalities, illness and stress, and neoplasms. Using modern reference collections and fisheries biology literature, initial attempts have been made to link these to causative agents. This study has identified age-related joint disease in older gadid fish for the first time, showing that these pathologies are to be expected in healthy wild populations.

17.1 Introduction

Fish bone pathologies are rarely discussed in the zooarchaeological literature, and, somewhat surprisingly, they are rarely mentioned in studies of modern fisheries biology either. This paper identifies the kinds of pathologies we can expect to find in fish bone assemblages from archaeological sites. Using large assemblages of fish remains recovered with the aid of modern excavation techniques, our study outlines the character and frequency of different pathological lesions, discussing potential aetiologies for each category. In so doing, we will explore whether or not fish pathologies have a role to play within zooarchaeology and associated disciplines.

Modern fisheries biology has an extensive literature relating to fish pathologies, primarily focussed on maintaining healthy stocks of farmed fish. As such, these fish rarely develop the severe physiological changes that are manifest in the skeletal record. The authoritative textbook *Fish Pathology* (4th edn) stretches to almost 600 pages, yet only three pages are devoted to bone and cartilage pathologies. Most examples relate to aquaculture: nutrient deficiencies (causing skeletal anomalies, fractures, and poorly ossified bones), temperature abnormalities (causing vertebral fusion, and skeletal anomalies), bacterial infections (causing bone erosion in extreme cases), pollution (causing deformities and vertebral fusion), and lightning strikes (causing luxation) (Roberts 2012, 138–140). All of these examples may have some relevance to archaeological specimens, but many of our examples are not readily explained in the literature.

17.1.1 Previous work

Pathological modifications in domestic mammals attract obvious attention from those caring for livestock (*e.g*. Bartosiewicz 2013; Davies *et. al* 2005), but wild animals have not been subject to such detailed attention. Wild terrestrial mammals may be observed and comments made about them (Bartosiewicz 2016), but aquatic animals are much more difficult to observe, let alone analyse and discuss in the literature. Odd or ill fish have no doubt been observed by fishermen, particularly when fishing old populations, but these animals seem to have rarely entered the scientific literature.

Fish bone pathologies were recorded in the 19th century, in a seminal paper that was one of the first to present a modern, systematic approach to tumours in animals (Bland Sutton 1885). Three examples were discussed in that work, including an amorphous exostosis on cod vertebrae, a cod maxilla with a disc-shaped "osseous tumour", and a pike dentary with an "exostosis […] it is finely spiculated and springs from the alveolar border of the bone" (Bland Sutton 1885, 429, figs 9–11). These examples and several others were discussed in a summary of modern fish, amphibian and reptile tumours, several of which included bony material (Schlumberger and Lucké 1948), and more recently, fish bone injuries and tumours were briefly discussed in the context of fossil palaeopathology (Rothschild and Martin 1993, 212–267).

Wheeler and Jones (1989) briefly discuss "aberrant" fish bones, noting that they were extremely rare in archaeological assemblages, although illness and physiological stress during the life of the fish could be visible in false growth lines in vertebrae, otoliths and scales (Wheeler and Jones 1989, 120). A single example of a cod dentary with an "abscess" was cited as the "only convincing example of a fish bone displaying a pathological condition known" (Wheeler and Jones 1989, 120). However, they also mentioned vertebral abnormalities in the form of fused vertebrae found on herring (*Clupea harengus*) and cyprinids (carp family) in larger assemblages (Wheeler and Jones 1989, 121). No otoliths feature in the current study – probably owing to their relative rarity in the sites considered – but Wheeler and Jones note that otoliths with a malformed crystalline structure are occasionally observed in modern fish (Wheeler and Jones 1989, 121).

Bone hyperostoses occur routinely in particular species or families and these are often discussed within the context of fish pathologies, albeit that the aetiology still remains unclear (Meunier and G. Desse 1986; Meunier and J. Desse 1994). These so-called "Tilly bones" include the characteristically swollen bones found in 22 different fish families (von den Driesch 1994; Jawad 2013, 1145). Common examples include haddock (*Melanogramus aeglefinus*) cleithra, supracleithra and posttemporals, and horse mackerel (*Trachurus trachurus*) cleithra (von den Driesch 1994). Hyperostoses such as these are species-specific, and are a useful attribute for taxonomic identification (Smith-Vaniz and Carpenter 2007). They are not necessarily pathological and can be termed "relatively harmless neoplasms" (von den Driesch 1994, 44). In rare circumstances hyperostoses can be viewed as pathological; examples from non-anthropogenic Pliocene/Pleistocene freshwater deposits in Tanzania are interpreted as a direct response to extreme environmental conditions (Schlüter and Kohring 2002). There, abnormally high levels of fluorine were identified in the pathological hyperostoses but *not* in the associated "normal" elements (Schlüter and Kohring 2002). Hyperostosis is generally viewed as

a non-pathological condition (Wheeler and Jones 1989, 121) and as such will not be discussed further.

17.2 Material and method

In common with many zooarchaeologists, the authors have always had a passing interest in pathological bones, but aside from making notes during primary recording we have seldom had the opportunity to publish any record of pathologies. One assemblage encouraged us to take things further.

17.2.1 Assemblages available for study

At Bon Accord, Aberdeen, a port city on the east coast of Scotland, a large and well-preserved assemblage of medieval, post-medieval and early modern fish remains was found, the bulk of the material dating to the late 12th to 14th century AD (Harland 2010). Most of this early material consisted of very large cod (*Gadus morhua*) and ling (*Molva molva*), half of which were of at least 100 cm total length (TL) with most of the remaining material from fish measuring 80–100 cm TL. From a total of about 7800 fish bones, 33 were identified as pathological. These specimens provided some examples of repeated pathologies, allowing some preliminary observations to be made about the elements affected and the nature of the pathological lesions observed. The prehistoric site of Doel, Belgium produced another 18 examples, from the final Mesolithic "Deurganckdok-sector B" area. This particular area of the Doel excavations produced a sizable assemblage of about 2000 bones, all but one of which were from freshwater taxa, primarily cyprinids (Van Neer *et al*. 2005). These were noted as pathological during analysis, and provide a useful addition to the large, carnivorous and marine fish assemblages from Scotland. These two sites formed the foundation for this study, but in order to expand upon this moderate sample, more assemblages were needed.

Several other sites analysed by the authors provided individual examples of pathologies, but none were of sufficient size to produce a large assemblage of pathological bone to match. The Viking Age and medieval site of Quoygrew, from the island of Westray in the Orkney archipelago off the north coast of Scotland (Harland and Barrett 2012), produced a substantial assemblage of fish remains, including 25 (unpublished) pathologies from the sieved fraction consisting of about 86,000 bones. The hand-collected fish remains had remained unanalysed, but they proved to be a fruitful source of pathological material. Several boxes of hand-collected material were available, and they proved very similar to the Bon Accord material in that they primarily originated from larger cod and ling. From these, another 189 pathological fish bones were identified, from a total estimated at around 150,000.

Other sites from the authors' experience have also contributed to this study, including 33 (unpublished) examples from Earls' Bu (Harland 2006), a high-status Viking and medieval site in Orkney. The Pool assemblage is chronologically similar and was available for examination in the Orkney museum archives. This provided another 48 examples (a few were briefly described by Cerón-Carrasco (1998), but the examples used here were extracted from the archives). Together, these sites produced 328 examples of

pathologically modified bones from North Atlantic fish species, primarily from the cod family. In addition to the zooarchaeological specimens, complete modern fish skeletons were also examined. These were primarily gadids (cod family), from the reference collections available to the authors, including fish skeletons registered at the Royal Museum for Central Africa (RMCA), the Royal Belgian Institute of Natural Sciences (RBINS) and Jen Harland's personal collection. These modern specimens are useful in that whole, individual fish are represented rather than the usual disarticulated and commingled remains.

17.2.2 Cataloguing and classifying

Each bone was entered into a spreadsheet with the following attributes recorded: site, context/provenance data, recovery, species, element, condition, fragmentation, zones (following Harland *et al*. 2003), side, total length estimate (as accurately as possible), full description, and hypotheses as to aetiology (a category that was reflexively revisited throughout the creation of the dataset). Most pathological fish remains were photographed using a Nikon 3200 DSLR with a scale, photographic lighting and a tripod angled to vertical. Photographs were then sorted and prepared for publication using Nikon ViewNX-i, Capture NX-D and GIMP.

The large size of the pathological collections has allowed an attempt at classification by type, although as with studies of aberrant mammal and bird bones, classification was not always straightforward and specimens may have multiple category designations (Bartosiewicz 2013, Chapter 6). We established and illustrated six different categories, based on a combination of physical appearance and suspected aetiology, as detailed below. Identification of any bone as pathological requires a detailed knowledge of "normal" morphology, including variants from the norm. It also requires the confidence to attribute a bone's abnormal appearance to pathology rather than assuming that it is from a species not previously identified. While some examples – such as fused vertebrae – are clearly abnormal, others are less obviously pathological, especially if fragmented or in poor condition of preservation. Reference collections for wild taxa are seldom complete and the temptation is often to record a slightly odd element to family or higher level, on the assumption that the bone is not pathological. Fish appear to have naturally low levels of pathological bones, so a specialist may see only a few pathologies despite years of work on tens of thousands of fish remains. Here, the identification of pathological bones is the result of years of familiarisation with the fish assemblages from the region, helped by access to very substantial well-preserved assemblages.

17.3 Results

17.3.1 Quantification

The Viking Age and medieval Scottish marine assemblages produced a total of 328 pathological fish bones, out of a total of about 313,000 fish bones. The final Mesolithic phase of Doel, Belgium produced another 18 examples, from an assemblage of just over 2000 bones. A small number of additional examples come from other sites analysed

Table 17.1. Sites, quantities and prevalence of pathological fish bones.

Site and source	*Pathological bones, N*	*Estimated TNB*	*NISP*	*Method of recovery*	*Fragmentation*	*Condition*	*TNB %*	*NISP %*	*Reference*
Quoygrew, Orkney	25	86,000	22,094	2 mm sieving	some	excellent	0.03	0.11	(Harland and Barrett 2012)
Earls' Bu, Orkney	33	63,200	17,300	mostly 2 mm sieving	high	poor	0.05	0.19	(Harland 2006; unpublished)
Doel, Belgium	18	2091	1200	2 mm sieving	high	poor, all burnt	0.86	1.50	(Van Neer *et al*. 2005)
Total sieved	*76*	*151,300*	*40,594*				*0.05*	*0.19*	
Bon Accord, Aberdeen	33	7800	4383	hand collection, some sieving	very little	excellent	0.42	0.75	(Harland 2010)
Quoygrew, Orkney	189	*c*. 150,000		hand-collected	some	excellent	*c*. 0.13		(Harland unpublished)
Pool, Orkney	48	*c*. 6500		hand-collected	some	excellent	*c*. 0.75		(Harland unpublished)
Total hand-collected	*270*	*164, 300*					*0.16*		
Grand total	*346*	*c. 315,600*					*0.11*		

by the authors, though the pathologies were often unpublished, with rarely more than a few examples per site. Table 17.1 shows the main sites used, together with recovery and taphonomic information. The sieved assemblages produced fewer pathological fish bones, with a total of about 0.05% of the total number of bones (TNB) classed as pathological (range 0.03% to 0.86%), or between 0.1% and 1.5% of the number of identifiable specimens (NISP). The hand-collected assemblages produced relatively more pathological bones, with a total of 0.16% of TNB (range between 0.1% to *c*. 0.5%). Approximately three times as many pathological fish bone could be expected from the hand-collected assemblages, though this broad generalisation may reflect regional taxa. For the one hand-collected site where NISP was available, pathological bones were about 0.75% of the NISP.

17.3.2 Classification

Detailed descriptions were taken of the pathologies, and attempts were made to classify them into groups based on similarities in appearance. This process was revised throughout the cataloguing procedure as patterns started to emerge. Six categories were ultimately formed, some more closely aligned to various element types than others (Table 17.2).

These categories are not definitive, nor are they exclusive: an aberrant element could easily fit within two or even more categories. However, it is hoped that these descriptions and illustrations will form the basis for further study.

17.3.2.1 Type 1: Injuries

Aside from age-related deformations, healed or healing injuries were the second most common types of pathological lesions observed, with 88 examples noted (Figure 17.1). They were found on the mouth elements of gadid fish, the lateral sides of neurocranium bones, and vertebrae. Examples include healed misaligned fractures (Figure 17.1, third row, left), possible luxation (a probable dislocation led to a new *fovea* formed on an opercular, Figure 17.1, second row, right), severe infection (Figure 17.1, bottom right) and abscess formation (Figure 17.1, top right). Many examples, such as the ceratohyal and the modern opercular in Figure 17.1 (second row, left and right) show only a small lesion on the medial side that would not have been that detrimental to the animal. Many of these bones are covered by only a thin layer of skin, and thus shallow, medial injuries found on bone would not necessarily be serious. New bone growth was occasionally noted on some of these pathologies, showing evidence of healing, as on the bottom left premaxilla in Figure 17.1. New growth often takes the form of "crusts" of bone with visible edges, and this new bone is often of different colour and/or texture.

A modern example shows the affects of injury on a cod of 110 cm TL (Figure 17.1, top left). This individual showed trauma to the medial articulation of both dentaries, with some amorphous new bone growth. The premaxillae remained normal, but the vomer was asymmetrical, shortened and fused in a block with the mesethmoid, ethmoid and prefrontal bones. Similar examples include the dentary in Figure 17.1 (third row, right). An initial injury could have led to the substantial remodelling visible in this dentary; alternatively, this individual could have suffered from tooth abscesses or even age-related joint disease.

Table 17.2. Relative frequency of pathology types by skeletal element; 1 star=infrequent, 5 stars=very frequent. Specimens may be recorded in multiple categories.

	Mouth elements	*Articular-quadrate*	*Appendicular skeleton*	*Vertebrae*	*Other elements*
1. Injuries	*****	*	**	**	***
2. Tooth 'abscesses'	****				
3. Age-related joint disease	**	****	**	*****	*
4. Congenital abnormalities	**		*	***	
5. Illness and stress				**	
6. Neoplasms	*	*	*	*	*

These injuries may have been caused by prey attempts from larger fish or other carnivores, although some injuries may have come from attempted prey fighting back. Escaping from fish hooks caught in soft tissue is another potential explanation for some of these external injuries, as hooks do not always catch in the mouth.

17.3.2.2 Type 2: Tooth "abscesses"

This category includes 46 examples on toothed elements, primarily the premaxillae and dentaries (main elements in the upper and lower jaws), as well as the vomer (a toothed midline element at the front of the upper jaw). These included many examples of what appear to be tooth abscesses – an identification based on mammalian analogy – with loss of teeth, loss of tooth "sockets", abscesses forming deep into the bone, and occasional remodelling with healing "crusts" (Figure 17.2).

Many examples of abscesses are small showing no associated bone remodelling (*e.g.* Figure 17.2, top row, modern example). Others are more extreme, with deep holes visible in the bone. The cod premaxilla in Figure 17.2, second row, exhibits a large abscess measuring 11 × 10 mm, extending about 4 mm deep, with new bone growth visible within the abscess showing some healing had started. The lateral tooth row had remodelled ventrally as though pushed down by the abscess. A further example (Figure 17.2, bottom left) shows a cod premaxilla with an abscess of 5 × 6 mm and 4 mm depth, located at the base of the ascending process, and a separate, smaller lesion that may have been caused by an internal abscess collapsing. In this case there is little evidence for any healing or new bone growth. A final example of a ling premaxilla (Figure 17.2, bottom right) shows a deep abscess but with new bone growth and healing. An abscess approximately 12 mm long, on the lingual side of the tooth row, is partly filled in by new bone growth suggesting considerable healing had taken place. Tooth "sockets" are not observed in this new growth on this or any of the other examples.

The frequency with which this pathology is observed in big individuals of the cod family may be related to their diet: these are carnivorous fish whose prey may strongly resist capture. Injuries to the mouth from struggling or escaping prey may result in wounding, tooth loss and subsequent infection. Similar abscesses have not been observed on the pharyngeal jaws (the toothed elements including the infrapharyngeals

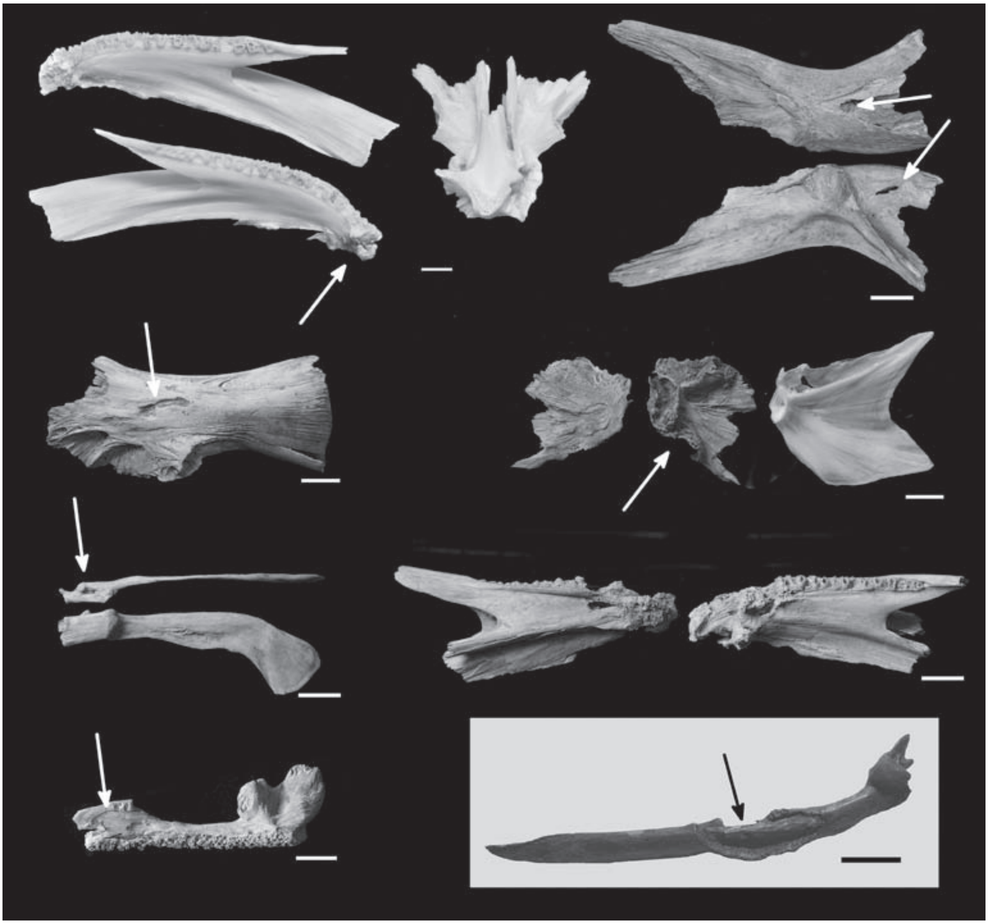

Figure 17.1. Examples of injuries. Top row, left: two dentaries and fused vomer/mesethmoid/ethmoid/frontals from a modern cod (RMCA 91017P58; 110 cm TL). Both dentaries show remodelling to the symphysis, while the upper vomer block is shortened, fused and distorted. Top row, right: lateral and medial views of a cod right cleithrum showing a thickened area to ventral of the scapular articulation, with formation of an abscess "pocket" and possible fistula to medial (QG159). Second row, left: lateral view of a cod right ceratohyal, showing linear lesions to medial (PL18). Second row, right: lateral and medial view of a cod(?) right opercular (PL10) shown with a modern cod right opercular with a slight lesion to lateral (F3156; 91 cm TL). Archaeological example shows thickening and new rough textured bone growth to lateral, and substantial remodelling and lipping around the edges of the fovea. Possible luxation just ventral to the fovea forming a fossa 12 mm × 7 mm × 6 mm deep. Third row, left: two views of a cod postcleithrum with a healed fracture overlapping by 10 mm (QG130). Third row, right: lateral and medial views of a cod right dentary with substantial new bone growth around the symphysis and complete loss of the anterior part of the toothplate (QG119). Bottom row, left: medial view of a left cod premaxilla showing patch of healed new bone growth to lateral (QG43). Bottom row, right: ling right maxilla showing extensive "peeling" of original bone surface with some healing (AB16). Scale bars=1 cm.

Figure 17.2. Examples of tooth "abscesses". Top row: lateral and medial views of a modern cod right dentary with small abscess and fistula visible to buccal. Tooth row exhibits some distortion and remodelling (RMCA A3001P09; ~110 cm TL). Second row: medial and lateral views of a cod left premaxilla with large abscess extending across the tooth row at the base of the ascending process, with some remodelling of the tooth row and new "crusting" bone growth to lingual (QG141). Bottom left: medioventral and medial views of a cod left premaxilla, an abscess to the base of the ascending process, with some thin "crusts" of new bone growth, and a depression on the lingual lateral side of the tooth row caused by bone loss to the interior of the corpus, possibly related to an internal abscess (QG77). Bottom right: ventral and medioventral views of a ling right premaxilla with a large abscess with remodelling and new bone growth, and with a thin stripe of tooth loss extending the length of the tooth row (QG7). Scale bars=1 cm.

deep within the throat), implying that an internal biological explanation for these pathologies is unlikely: they occur at the front of the mouth where food enters. Future work may therefore place these lesions within the Type 1 "injury" category.

Injuries from hooks are another possible explanation for "abscesses" and Type 1 injuries to both mouth and lateral cranial elements as large fish in the cod family were primarily fished using hook and line in the past. Hooks do not always embed themselves in the mouth and could graze or embed in soft tissues around the head. If fish manage to escape from shallowly inserted hooks, the resulting injury could cause tooth trauma with resulting infection.

An example from a modern cod of *ca*. 110 cm total length shows an abscess to the right dentary, forming a hole about 9 mm wide on the lingual side just ventral to the

tooth row (Figure 17.2, top row). On the buccal side, a small hole of *ca*. 2 mm diameter was visible which may have functioned as a fistula. The tooth plate was pushed into a medial direction with some "sockets" missing. Although the fishing method and cause is unknown in this modern specimen, the remaining elements were normal making these abscesses appear localised.

17.3.2.3 Type 3: Age-related joint disease

As with older mammals, some of the biggest and oldest fish in the assemblages analysed appear to have developed age-related wear to the major joints in the skeleton, particularly the articular-quadrate joint and between the vertebrae. This was the most common category recorded, with 181 examples noted. This pathology type was primarily observed on the bigger and older fish, many of which were estimated to be in excess of 100 cm TL. The joint formed between the articular and the quadrate acts as a hinge to open and close the lower jaw, and considerable force may be needed to capture and maintain prey amongst the carnivorous fish (Westneat 2006, 33). Numerous examples of widened, thickened and splayed articular surfaces have been noted for both articulars and quadrates, with some exhibiting patches of eburnation and grooving (*e.g*. Figure 17.3, top row, right, and bottom row, left). Some have considerable new bone growth around the articular surface with remodelling of the joint (*e.g*. Figure 17.3, second row, left). One context from Quoygrew contained pathological elements which could be refitted, showing that the age-related arthropathies affected both elements of this joint (Figure 17.3, third row). A modern example, a large golden grouper (*Epinephelus costae*; 69 cm TL; RMCA 88019P142) from the Gulf of Guinea, also shows that both the articular and quadrate could be affected by age-related changes. The medial symphyses of the examined gadid dentaries were also susceptible to age-related changes, with small areas of eburnation observed in one case. The articular crest of the maxillae also appears predisposed to age-related wear (*e.g*. Figure 17.3, top left), with instances of eburnation, bone loss and luxation noted (although extreme examples could also be related to injuries). Occasionally a cleithrum and scapula are found fused or fusing in these large and old fish, and may also be age-related. This is not restricted to the cod family: a large ballan wrasse (*Labrus bergylta*) from a Late Bronze Age/Early Iron Age site in Orkney displays a fused cleithrum and scapula (Harland, unpublished). Other examples would be expected in healthy fish populations with large numbers of older fish.

Age-related changes to the vertebral column are also consistently noted (*e.g*. Figure 17.3, second row, right and bottom row, right). Although vertebral abnormalities are fairly common and varied (see Type 4), some types of abnormalities only appear in quantity in older individuals. Typically, the articular surfaces develop extra bone growth around the lateral edges of the articular surfaces and the vertebral bodies become splayed. In more extreme examples, vertebrae start to ankylose with some antero-posterior compression of the vertebral bodies.

17.3.2.4 Type 4: Congenital abnormalities

This broad category comprises 40 examples and spans all elements. It can include both conditions that are odd though not necessarily pathological, as well as those that are

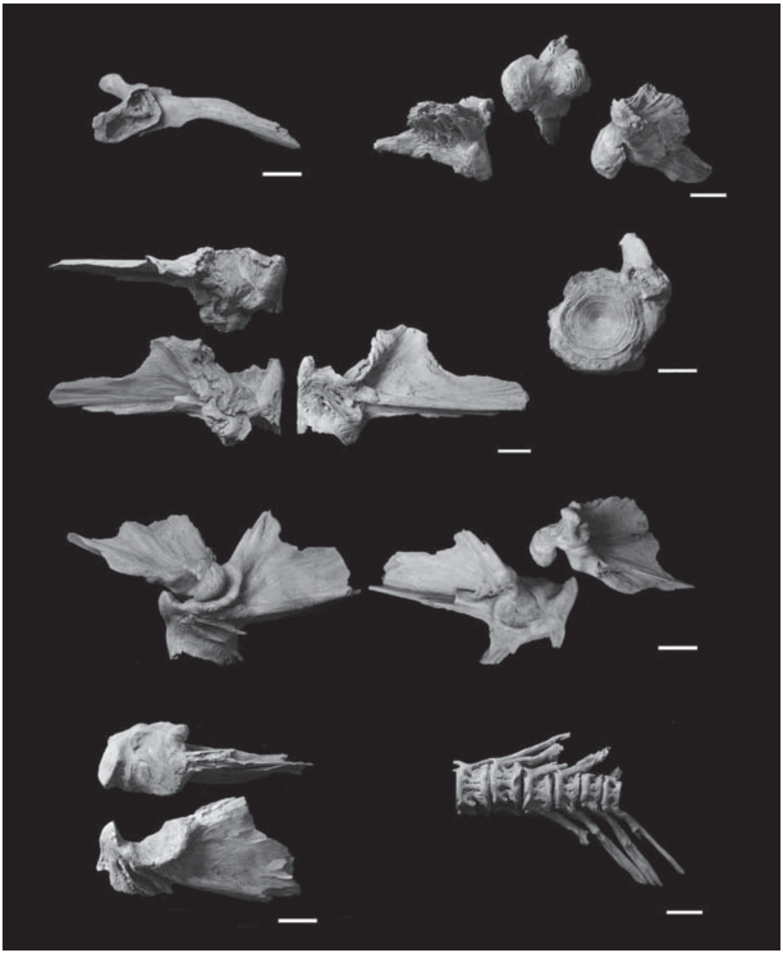

Figure 17.3. Examples of age-related joint disease. Top row, left: mediodorsal view of right cod maxilla showing severe loss of articular crest with remodelling, potential luxation and fistula (QG108). Top row, right: dorsal, anterior and medioventral views of a cod right quadrate with very extensive thickening and widening of the trochlea, with eburnation and grooving across both condyles (PL31). Second row, left: dorsal, medial and lateral views of a cod right articular with new bone growth all around the articular surface extending 10 mm to medial and 12 mm to dorsal (QG90). Second row, right: cod abdominal vertebra with thickened, rough area of bone splaying out from the margins of the articular surface (QG84). Third row: lateral and medial views of a right quadrate and articular from the same cod, both with age-related joint changes, including thickening, widening of the articular surfaces, and eburnation on the medial condyle of the quadrate and on the middle and medial surface of the articular articulation (QG88&89). Bottom row, left: dorsal and lateral view of a cod right articular exhibiting thickening and widening of the articular surface, and eburnation covering a depression on the medial side of the articular surface (QG40). Bottom row, right: series of 6 cod caudal vertebrae with thickening and splaying of vertebral centra, and thickened bone growth to neural and haemal spines (PL33). Scale bars=1 cm.

detrimental to the life of the fish. Extra tooth patches are relatively common on mouth elements, for example in Figure 17.4, bottom left.

Many spinal deformities fit within this category, although some may also develop as a result of illness or environmental stress (see Type 5). Fused vertebrae are relatively common, and are found in younger as well as older fish suggesting no (or much less) of a correlation with age compared to Type 3 abnormalities. Some may exhibit antero-posterior compression of the vertebral bodies with loss of the inter-vertebral space (*e.g*. Figure 17.4, third row, left). Spinal abnormalities include scoliosis (forming a zig-zag shaped spine), lordosis (the position of the tail is lower than expected) and kyphosis (the tail is higher than expected). A modern haddock of 61.5 cm TL illustrates scoliosis within the posterior abdominal vertebrae (Figure 17.4, top left). Kyphosis is shown on a modern pollack of 62.5 cm total length, with ankylosis extending over several vertebrae (Figure 17.4, second row). Modern studies indicate around 6% of wild young cod from clean waters will naturally exhibit some form of vertebral deformity visible in the skeleton, including compression, ankylosis, scoliosis and lordosis/kyphosis (Fjelldal 2009, 9–10). Archaeological examples of single vertebrae with scoliosis, lordosis and/or kyphosis are relatively common, and occasionally several may be found in articulation (*e.g*. Figure 17.4, top row, right and bottom row, right). This is not unexpected given the evidence from modern, wild sourced cod.

So-called "pug-headed" or "bull dog" cod are known both historically and from modern examples of farmed fish (Jawad *et al*. 2015). They characteristically exhibit a shortened upper jaw and neurocranium, with some deformation and asymmetric twisting (Jawad *et al*. 2015, 293). The lower jaw can be slightly distorted on one side (Jawad *et al*. 2015, 292). An asymmetric, twisted and shortened parasphenoid from a large cod may be one of these (Figure 17.4, third row, left), and other examples of twisted or shortened cranial elements have been observed. These abnormalities do not appear to adversely affect the animal, as they can live to old age. Historically, they were known in Norway as *kongetorsk*, or "king cod", and they were thought to lead spawning migrations (Jawad *et al*. 2015, 291).

17.3.2.5 Type 5: Illness and stress

Illnesses and physiological stress during an individual's life can be read in the skeleton. Wheeler and Jones (1989, 120) noted that "false" growth rings in otoliths, scales and vertebrae can be indicative of heavy parasite burdens, spawning stresses, or poor environmental conditions including food shortages. Scales are rare archaeologically, and are difficult to identify, even from well-preserved and sieved assemblages. The addition of pathological abnormality to their archaeological analysis would probably lead most fish specialists to class them as "unidentified" rather than attempt a species-level attribution. In this study, 13 vertebrae were noted with visibly abnormal growth rings from the North Atlantic material (*e.g*. Figure 17.5, top). One or more growth rings tended to be poorly ossified, suggesting the individual was in poor health and unable to grow and lay down bone normally for a time, before resuming normal health in subsequent years.

Studies of modern fish indicate the skeleton responds to inadequate nutrition or extreme conditions, like those found in aquaculture or modern polluted environments.

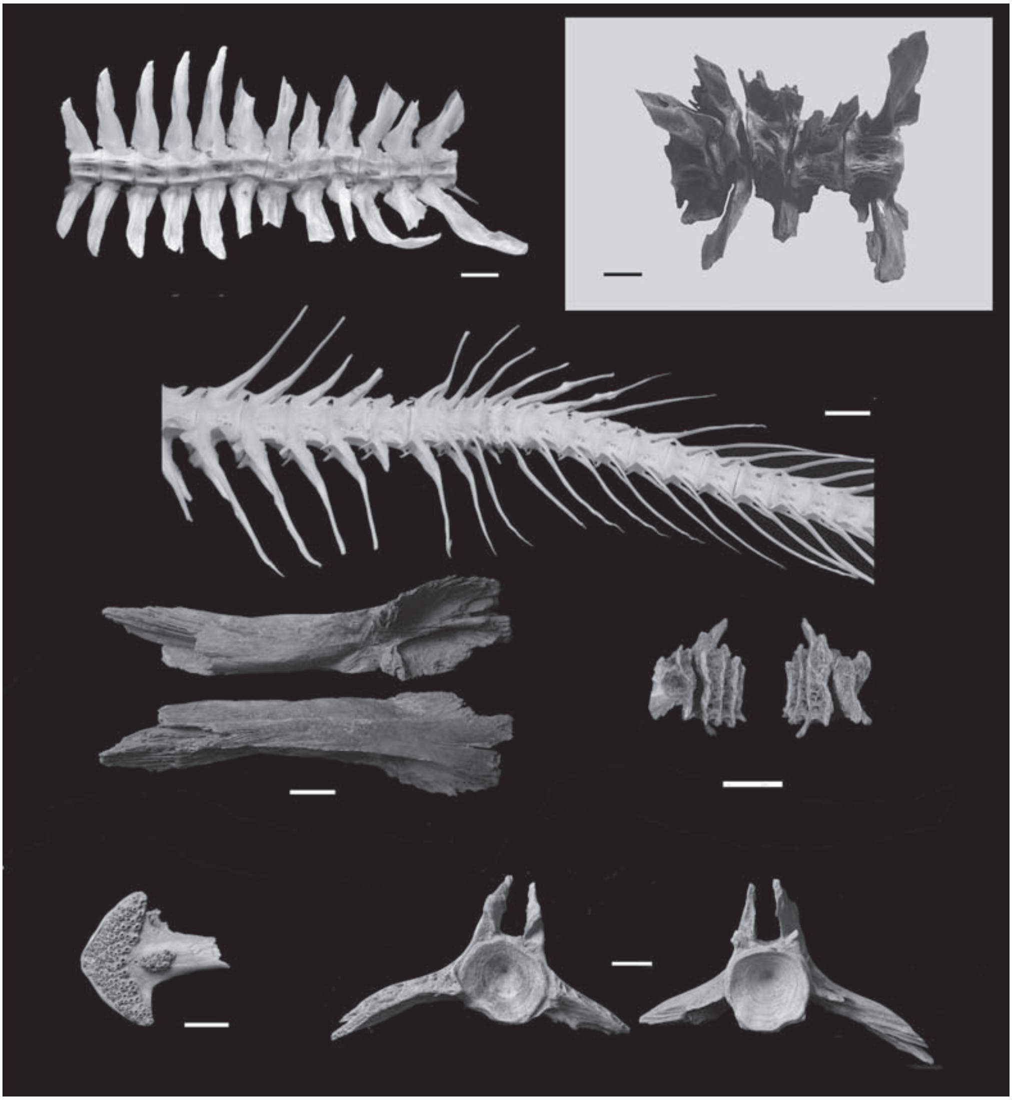

Figure 17.4. Examples of congenital abnormalities. Top row, left: ventral view of modern haddock abdominal vertebrae with mild scoliosis (RBINS 23810; 61.5 cm TL). Top row, right: ventral view of articulated cod abdominal vertebrae displaying scoliosis, compression of vertebral centra, splaying of articular facets, and some possible lordosis/kyphosis (AB9). Second row: left lateral view of modern pollack showing kyphosis, with some compression and ankylosis (RBINS 23519; 62.5 cm TL). Third row, left: ventral and dorsal view of cod parasphenoid showing shortening and twisting (QG100). Third row, right: left and right lateral views of series of gadid caudal vertebrae, three ankylosed and collapsed, with a further vertebra distorted but not yet ankylosed (EB16). Bottom row, left: cod(?)vomer with unusual extra tooth "sockets" (QG67). Bottom row, right: anterior and posterior views of a cod abdominal vertebrae with scoliosis and slight lordosis (PL9). Scale bars=1 cm.

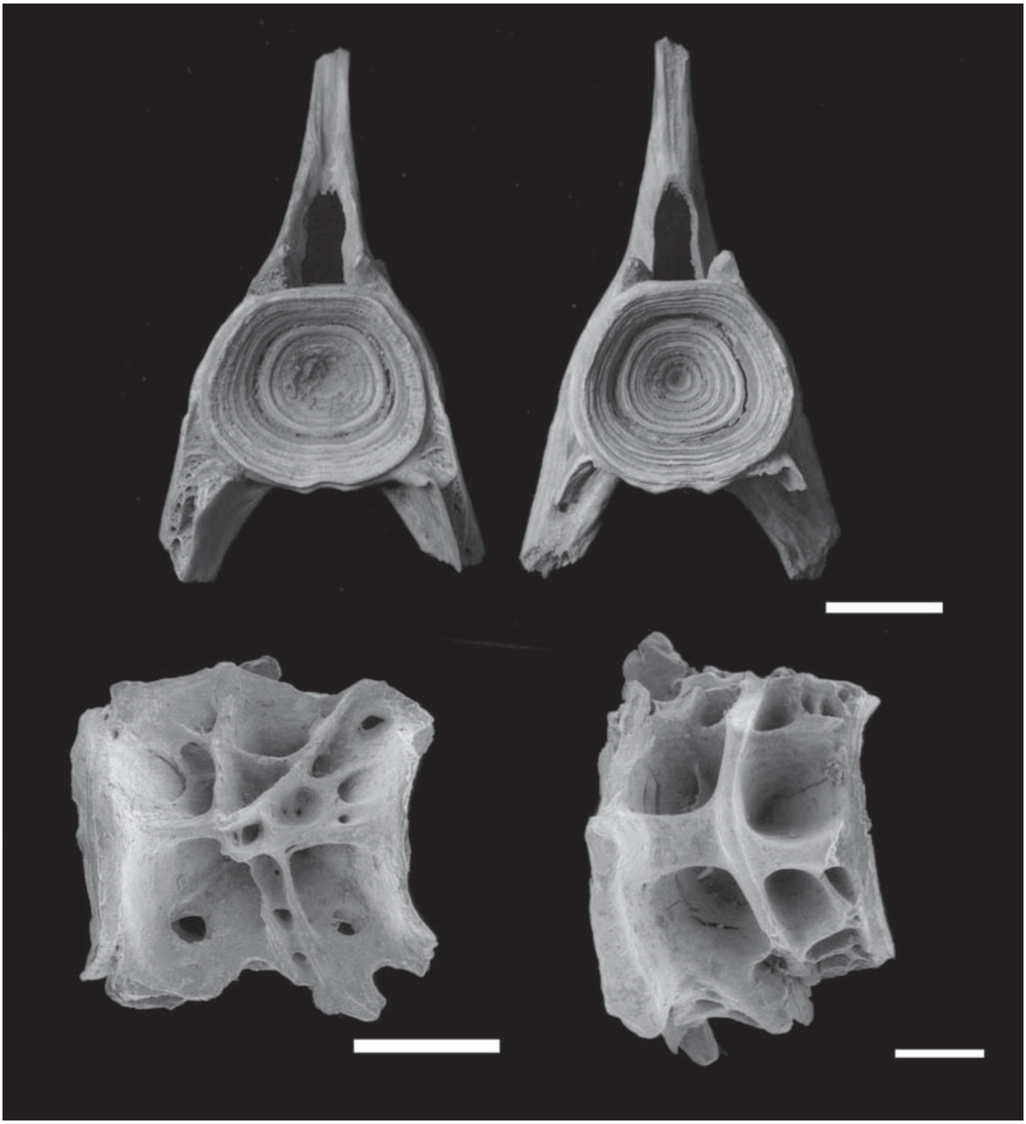

Figure 17.5. Examples of changes related to stress or illness. Top: anterior and posterior views of a ling abdominal vertebra showing poor ossification of a growth band on both articular facets, with subsequent recovery in later years (PL23). Bottom left and bottom right: two examples of fused cyprinid caudal vertebrae from Doul. Scale bar 1 cm for top and 1 mm for bottom.

Within the cyprinid family these responses can include a high rate of malformations in the vertebral column (Slooff 1982). Examples from the past are rare because ancient environmental conditions *should* have been ideal (though hyperostosis may form as result of extreme environmental conditions: Schlüter and Kohring 2002). The

18 examples of fused vertebrae included here from Doel could reflect a period of poor environmental conditions (Figure 17.5, bottom). These cyprinids have a very high rate of vertebral fusion, with 1.5% of the identified bones displaying pathological traits. Yet these bones originate from rather small fish (mainly of 10–20 cm standard length). Age-related joint disease can therefore be excluded. Other sites examined by the authors have produced numerous cyprinid remains, but virtually no pathological examples have been noted. However, Wheeler and Jones (1989, 121) noted that vertebral fusion in cyprinids were occasionally observed in sufficiently large assemblages. Environmental conditions at this final Mesolithic site may have placed stress on the resident fresh water fish community, albeit that the exact cause (high salinity, temperature, food shortage, *etc*.) remains unknown (Van Neer *et al*. 2005, 293).

17.3.2.6 Type 6: Neoplasms

This final category includes instances of tumour-like growths. These can be substantial and amorphous, and in highly fragmented find materials they can be difficult to identify even to skeletal element. Fifteen examples were noted. All examples here are on large, old individuals representing the cod family, indicating that there may be an association with age, for this family at least. A large example on an articular bone from Bon Accord extends approximately 20 × 10 × 15 mm from the lateral side, just anterior to the articular-quadrate joint (Figure 17.6, top). Radiography shows the mass of bone to be solid and amorphous. Other examples include an entire ling neurocranium found in articulation, with new granular bone growth, thickening to the skull and what appears to be a fistula (Figure 17.6, middle). Similar but highly fragmented examples of skulls attributable to the cod family have also been found (*e.g*. Figure 17.6, bottom). Their aetiology is not well understood.

17.4 Discussion

Six types of pathological abnormalities have been distinguished here:

Type 1: injuries,
Type 2: tooth “abscesses”,
Type 3: age-related joint disease,
Type 4: congenital abnormalities,
Type 5: illness and stress,
Type 6: neoplasms.

This classification system is derived from examination of a large number of fish remains, but may be biased toward the fish remains recovered from sites around the North Sea, particularly the cod family fish found in Viking Age and medieval deposits in Scotland. These fish are predominantly old and liable to age-related skeletal changes; they are also carnivorous, entangled in food chains where they are both predator and prey. This may explain the preponderance of Types 1 (injuries), 2 (tooth “abscesses”) and 3 (age-related joint disease) pathological lesions here. The small assemblage of freshwater cyprinids from Doel showed the highest rate of pathological alterations of

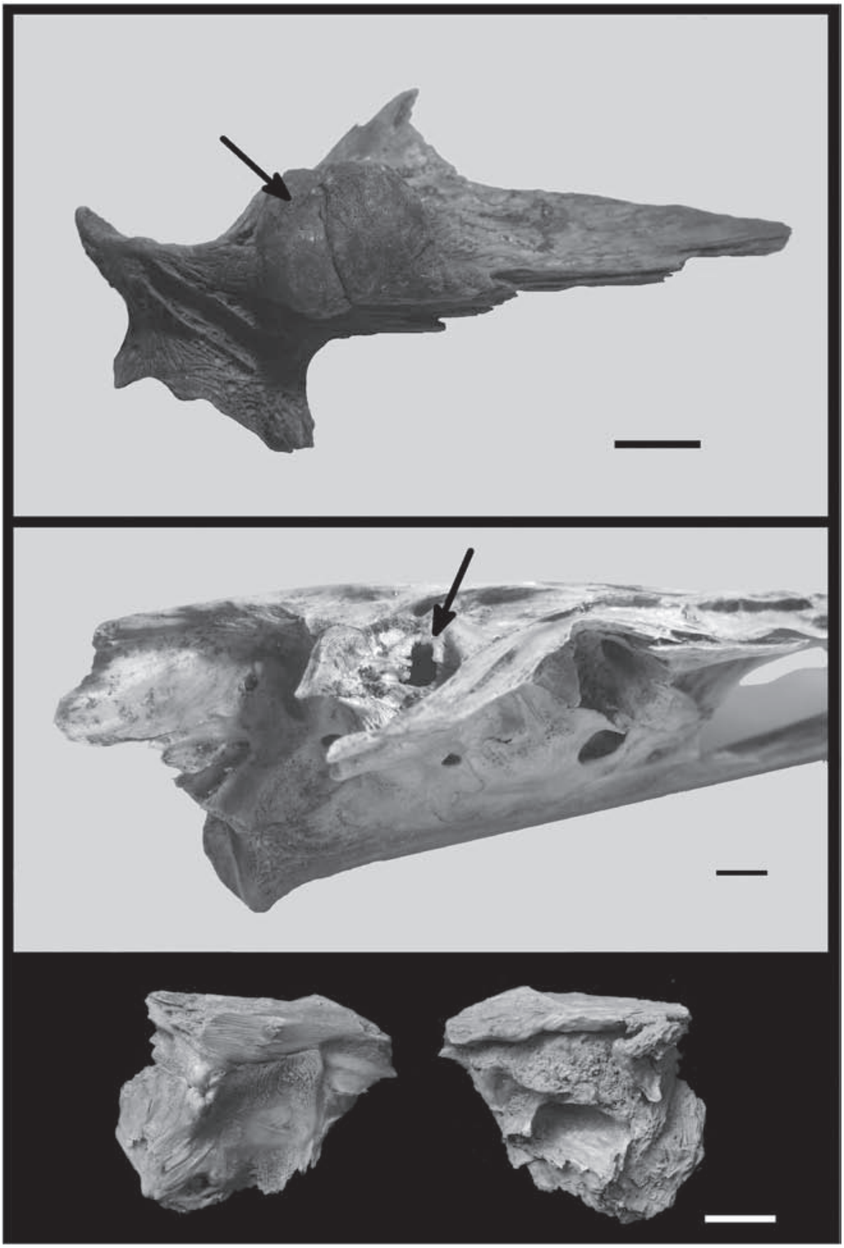

Figure 17.6. Examples of neoplasms. Top: lateroventral view of cod right articular with large neoplasm to lateral, with densely whorled new bone growth (AB13). Middle: right lateral view of ling neurocranium showing unusual fistula with thickened, granular bone growth (AB24). Bottom: left lateral and medial ventral views of ling neurocranium containing fragments of the basioccipital, parasphenoid, prootic and exoccipital, with thickening and granular new bone growth to medial, and exotosis to lateral (PL11). Scale bars=1 cm.

any assemblages studied, and all of these were Type 5, related to stress most probably caused by poor environmental conditions.

The high rate of congenitally malformed vertebrae in this cyprinid population shows that non-anthropogenic environmental stress can be manifest even in wild fish populations. This final Mesolithic freshwater site must have been subject to a period of poor conditions, potentially related to climate change, access to food, or high salinity levels, stresses affecting vertebral development in young cyprinids. Such pathologies could even be used as indicators of anthropogenic environmental degradation, including increased siltation, the pollution of freshwater environments by particulate terrestrial clastic material.

This classification system presented in this paper includes some categories that are known from modern studies of farmed and wild fish. Type 4 congenital abnormalities are very high amongst farmed cod, particularly vertebral deformities and "pugheadedness" (*e.g*. Fjelldal 2009; Jawad *et al*. 2015). Their identification in wild populations is expected in low quantities. What has been more surprising is the high proportion of Type 2 and Type 3 pathological conditions. These "tooth abscesses" and age-related joint diseases are not known from modern studies of wild or farmed gadids. Age-related changes observed here include eburnation and grooving to articular surfaces, as well as widening, splaying and thickening to joints. These are particularly apparent in the articular-quadrate joint, but are also observed on the dentaries, maxillae, in the posttemporal-supracleithral joint, and the vertebrae. There is a preponderance of older, adult and mature fish in the archaeological assemblages studied; modern fish populations are seldom allowed to develop a "natural" population structure that includes high quantities of old, mature fish.

A single large pike dentary was observed with a Type 2 lesion, from a British Bronze Age site (Harland unpublished), very similar to the specimen described by Bland Sutton (1885, 429, fig. 10). Pike are carnivorous fish, just like species in the cod family, so it would be unsurprising that they would also suffer from tooth abscesses possibly caused by escaping or fighting with prey. Other large, carnivorous fish may be expected to develop similar traumatic lesions.

In the assemblages we have studied, pathological remains were rare but the large size of the assemblages allowed us to calculate relative frequencies. For similar assemblages, we would expect to find about one pathological specimen for every 2000 normal bones identified. For the hand-collected bone, we could expect one pathological bone for about every 600 normal bones identified, although this rate was quite variable between individual sites. Herring remains are commonly found in their thousands in archaeological deposits around the British Isles, but pathologies are rarely observed. A 16th-century shipwreck contained about a dozen barrels of preserved herring and over 15,000 identified bones (Harland 2009). About 244 of these were identified as "fused" during analysis, including many pairs of vertebrae. However, upon closer examination almost all of these "fusions" were taphonomic in nature, caused by external matter forming concretions on the bone. They were only found in specific areas and were closely correlated with spatial patterning on the seabed environment (Harland 2009, 11). Only six instances of fused vertebrae actually showed morphological change to the vertebrae, in the form of compression of the vertebral bodies. This gives a rate of one pathological bone for every 2500 normal

bones, and this could be applied to other assemblages containing large quantities of herring.

Attempts have been made to link each pathology type to aetiology. However, causes of fish diseases that affect the bone are not well understood, as much of the literature relating to modern fisheries biology only concerns soft tissue changes (*e.g.* Roberts 2012). The role of parasites, bacterial infections and diseases on skeletal change is not well understood, and yet these may be the sole or a contributing cause of several of the abnormalities encountered in archaeological fish bone assemblages.

17.5 Conclusions and future work

To return to our title: do fish bone palaeopathologies have a role to play within zooarchaeology and related disciplines? This study has attempted to provide the first classification system for fish palaeopathology. Much is not yet known regarding aetiology and future work will help to unravel the relationships between the six pathology types and their causes. We have distinguished between pathologies caused by injury and those present naturally. Based on comparisons with mammalian and avian palaeopathological work and fisheries literature, the six categories of pathological modifications include injuries accumulated during the life of the fish (Type 1), and tooth "abscesses" (Type 2); the latter is not yet well understood but is common amongst large gadids. Many of the causes of the observed lesions are not yet known, but based on modern fisheries biology literature, attempts have been made to separate out the naturally occurring congenital abnormalities (Type 4) and neoplasms (Type 6) from those which are related to age (Type 3) and environmental stress (Type 5). These are distinct from the common non-pathological bone hyperostoses observed in several fish taxa.

Age-related joint diseases have been observed in fish populations for the first time. These have been identified on the basis of analogy with mammalian arthropathies in that eburnation, grooving, widening and splaying of the articular surface have been repeatedly observed in very large, and very old cod and ling. These pathologies should be observed – at low levels – in healthy populations of fish populations showing a natural age profile. This in itself has ramifications for fisheries biology: identifying age-related pathologies could be used alongside age profiles to question fishing pressures in marine ecosystems. No modern studies of gadids have reported on these pathologies in wild populations today, although their absence in the literature could reflect a lack of reporting rather than a real absence. The presence of these age-related pathologies within archaeological material may possibly be used as an indicator of a healthy age profile within an un-exploited ecosystem, as seen around the northern North Sea and around Orkney's waters in the Viking Age and medieval periods. Environmental stress, including those potentially of anthropogenic origin, can be ascertained from high rates of congenital abnormalities in fresh water ecosystems. Future work could use this pathological signature as a means of identifying "stressed" fish within the archaeological record.

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18. Skeletal Anomalies in Medieval and Early Modern Fish: A Case Study from Castle Kastelholm in the Baltic Sea

Hanna Kivikero

During the analysis of bone material from Kastelholm Castle in the Åland islands a number of anomalous fish bones were documented. The bone material comes from medieval and early modern contexts and the fish were most likely locally caught in the Baltic Sea. The current literature on fish biology points to abnormalities possibly caused by vitamin and mineral deficiency.

18.1 Introduction

The castle of Kastelholm is located in the northern Baltic Sea, midway between Sweden and Finland. The island is nowadays part of Finland, but from the 13th century until 1809 it belonged to the Swedish realm. The castle was founded at the end of the 14th century, between 1384 and 1387 (Hausen 1934, 4–6) on an oblong island or peninsula, but a land connection existed already in the 17th century due to isostasy (Figure 18.1). The inlet on the northwestern and eastern side of the castle leads to the coastal basin of Lumparn, and from there to the Baltic Sea. The castle was first mentioned in 1388 as one of the castles to be turned over to Queen Margareta after the death of Bo Jonsson Grip (Hausen 1934, 5). A fire destroyed almost the entire castle around 1619/1620. A period of slow decay started in 1634 when the administrative posts attached to the castle were moved to Turku. Fires in 1745 and 1772 left the castle more or less in ruins (Mäkinen 2004, 117–121).

Kastelholm was strategically positioned halfway between the mainland cities of Stockholm (west) and Turku (east), approximately 170 km from each. The purpose of the castle was to defend the Åland Island, oversee trade and to collect taxes from the local peasants. The taxes were paid in money or in natural products. In 1549, the peasants were expected to deliver rye, barley, malt, flour, bread, hops, butter, seabirds and meat. A list of goods transported to the castle also includes freshwater and sea fish: herring, perch, roach, pike while the island of Kökar provided cod (KA 2624) to the castle. Most of the food products were consumed at the castle but some were to be shipped to the castle of Stockholm, where the king resided. In Stockholm, the products were either consumed or further distributed to other parts of Sweden (Hammarström 1956, 85). Fish was a natural commodity for the people in Åland because of the easy access to the sea all year round. The islanders produced a variety of fish products that

Figure 18.1. Map of Åland in the Baltic Sea. Castle Kastelholm is marked with a dot. Map by Rudolf Gustavsson.

were salted or dried, including pike, perch, carp fishes (roach, common bream, ide), cod and herring (KA 2608, KA 2619, KA 2920). The peasants drew a distinction between 'fish' and herring, with fish generally referring to species with scales (Storå 2003, 21–22).

18.2 Fish bone material from Kastelholm

The castle underwent modern renovation already at the end of the 19th century, to reconstruct a romantic idea of the castle landscape. The first archaeological excavations were conducted in 1950. Between 1965 and 1998 excavations were done almost every year. The aim of the enquiries was to produce material which would be used in

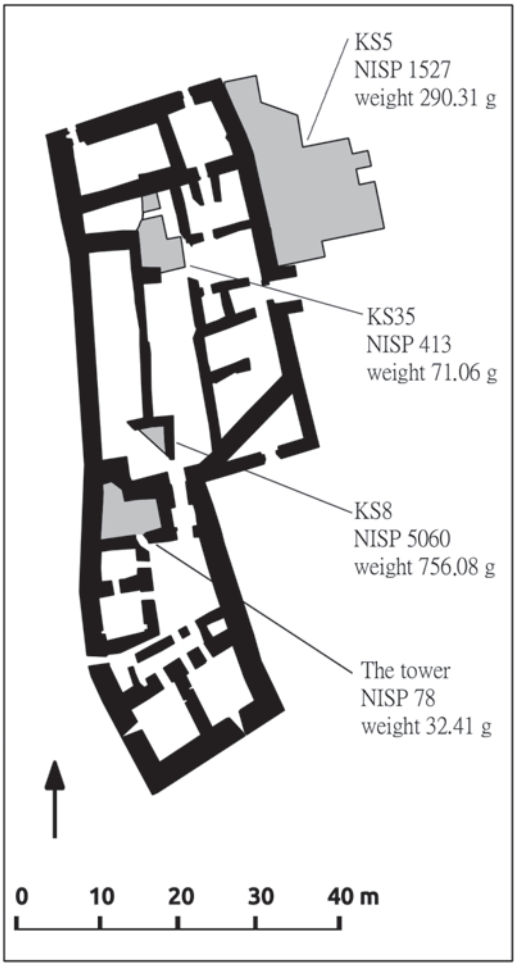

Figure 18.2. Map of the analysed areas with the amounts of fish bones retrieved. Map by Rudolf Gustavsson and Hanna Kivikero.

restoration work and excavations were carried out both inside and outside the castle walls. The castle was to serve as a museum. Excavations have also been conducted in conjunction with various technical installations done in the castle ruins, which meant that no specific questions were expected to be answered. The bones were mainly hand-collected and retrieved using a 10 mm mesh.

The bone material consists the total of 5.5 tonnes of animal remains and comes from different time periods, from the 14th to the 18th century. In 1983 Ronnie Carlsson identified 17 kg of mammal and bird remains, but the fish bones remained unexamined. Between 2012–2014 a total of 142 kg of the bone material, from excavations conducted in 1980–1985, was analysed by Hanna Kivikero and Rudolf Gustavsson. The aim was to understand the fauna and food produce in Kastelholm. The bone material comes from both inside and outside the castle (Figure 18.2) and is interpreted to be food waste. Fish bones make up 1.15 kg of the total amount analysed. The large mesh size used during the excavation has probably detrimentally affected the representation of small fishes, such as herring, in the sample.

The bone material contains some of the same species that are mentioned in the list of products taxed and consumed at the castle, such as pike (*Esox lucius*), perch (*Perca fluviatilis)*, roach (*Rutilus rutilus*), ide (*Leuciscus idus*), cod (*Gadus morhua*) and herring (*Clupea sp*.) (Table 18.1). Other species identified in the material were common bream (*Abramis brama*), zander *(Sander lucioperca*), whitefish (*Coregonus sp*.), burbot (*Lota lota*), salmon (*Salmo salar)*, fourhorn sculpin (*Myoxephalus quadricornis*) and sturgeon (*Acipencer sturio*). These species could be locally fished due to the unique environment of brackish water in the geologically young Baltic Sea (Voipio 1981; Björck 1995).

Table 18.1. Fish species identified in Castle Kastelholm.

Species	*1300–1400*	*c. 1400*	*1400–1450*	*1450–1500*	*1400–1500*	*1500–1550*	*1550–1600*	*1600–1700*	*1300–1600*	*Total*	*% total*
Common bream (*Abramis brama*)									1	1	0.01
Ide (*Leuciscus idus*)					3	5	18	3	1	30	0.42
Roach (*Rutilus rutilus)*	1				6	2	3	5	3	20	0.28
Carp fish (Cyprinidae)	79		8	1	154	80	127	34	12	495	6.99
Perch (*Perca fluviatilis*)	173	1	6	3	411	165	96	21	47	923	13.04
Zander (*Sander lucioperca)*						2		3		5	0.07
Pike (*Esox lucius*)	73	3	51	15	291	581	297	133	202	1646	23.26
Whitefish (*Coregonus sp.)*	1		1		3	2			1	8	0.11
Burbot (*Lota lota)*						2	1			3	0.04
Salmon (*Salmo salar)*					1	11		1	3	16	0.23
Cod (*Gadus morhua*)	35		3	4	241	81	43	15	15	437	6.17
Herring (*Clupea sp.*)					3				1	4	0.06
Fourhorn sculpin (*Myoxocephalus quadricornis)*	1				1		1			3	0.04
Sturgeon (*Acipenser sturio*)					1		1			2	0.03
Bonefish (Teleostei)	465	2	14	10	1646	543	431	200	174	3485	49.24
Total	828	6	83	33	2761	1474	1018	415	460	7078	100

18.3 Anomalous fish bones from Kastelholm

Skeletal anomalies were identified in four of the best–represented identifiable taxonomic groups: the family of carp fishes (Cyprinidae), pike, perch and cod. Out of 7078 fish bones, such changes were noticed in a total of 15 remains: 11 bones from KS8, three in KS35 and one in KS5. These specimens represent 0.2% of the total number of fish bones and 0.4 % of the identifiable specimens (NISP 3,593). Size and age estimations were not available for the bones in question.

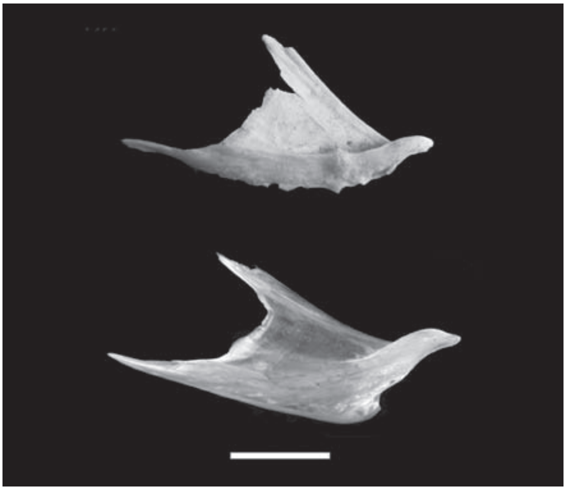

Figure 18.3. Posttemporal bone of a pike showing excess bone formation (top) and a healthy reference specimen (bottom). Scale=1 cm.

Figure 18.4. A hyomandibular bone of a pike deformed by a crooked anomaly causing major deformation (left) and a healthy reference specimen (right). Scale=1 cm.

Of the 546 cyprinid bones (including those successfully identified to species), one showed hyperostotic growth in the arch of the caudal vertebra and could be linked to similar phenomena reported by von den Driesch (1994, 41). The pathological nature of the anomaly is unclear. The bone came from a context in KS8, dated to the 15th–16th century. A total of 1646 pike bones were identified in the material, whereof abnormalities were documented on five. Three cleithra with hyperostosis were found in two different contexts: AD 1500–1550 in KS8 and AD 1300–1600 in KS35. Furthermore, a posttemporal bone from 14th–15th century shows a possible osteoma, 3 mm in diameter, on the surface of the bone (Figure 18.3). A hyomandibular with a smooth, crooked deformation (Figure 18.4) was retrieved from an AD 1500–1550 context in KS8.

Only one perch bone, from the total of 923 identified specimens, showed an anomaly: an entopterygoid bone, which shows a possible osteoma, 3 mm in diameter (Figure 18.5), was found in the same context as the pike hyomandibular bone.

There were 437 cod bones identified in the material and abnormalities were found in eight, all from 15th–16th-century contexts in KS8. There were two sets of precaudal vertebrae which were fused together. These specimens were counted as one. Four caudal vertebrae showed signs of osteophytes. One opercular showed extra bone formation around the articular surface. The bone formation had a smooth, slightly wavy structure. It was recovered from a 15th–16th-century deposit in KS8.

In one of the fused precaudal vertebrae, osteophytes can be observed around the body and at the root of the neural arch and pleural costae (Figure 18.6). This has caused the body to widen by *c*. 2 mm. The bone formation has a wavy structure which is relatively smooth. The three vertebrae have fused together from the body. The fused surface is smooth with an expansion of the body. In result, the mid-section of each vertebra seems to be relatively smaller.

The other set of fused vertebrae (Figure 18.7) has a fused body similar to the specimen shown in Figure 18.6. The bodies of the three precaudal vertebrae are fused together and the fusion surface is smooth with a slight expansion of the body so that the mid–section of each vertebra seems to be smaller. Osteophytes can be observed in both cranial and caudal surfaces of the body. The cranial surface is uneven with a smooth wavy structure and has a slightly rectangular form.

Four caudal vertebrae were documented with osteophytes on the lateral edge of the neural arch (Figure 18.8), giving the bone a swollen appearance. The osteophyte growths are mostly limited to one side of the vertebra. The topmost vertebrae in Figure 18.8 show osteophytes in the haemal arch around the body on the cranial side. Two of the vertebrae show changes in the rings of the body, creating a slight protrusion on the topmost rings.

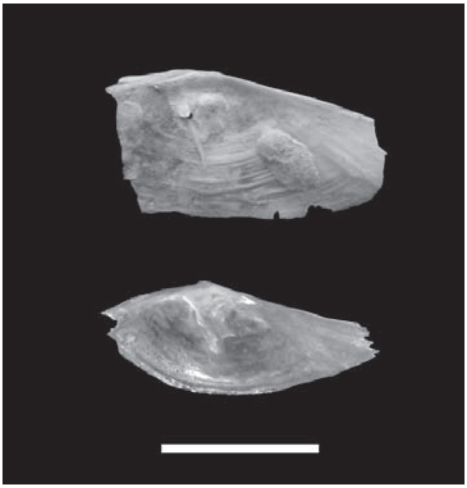

Figure 18.5. Entopterygoid bone of a perch with excess bone formation (top) and a healthy reference specimen (bottom). Scale=1 cm.

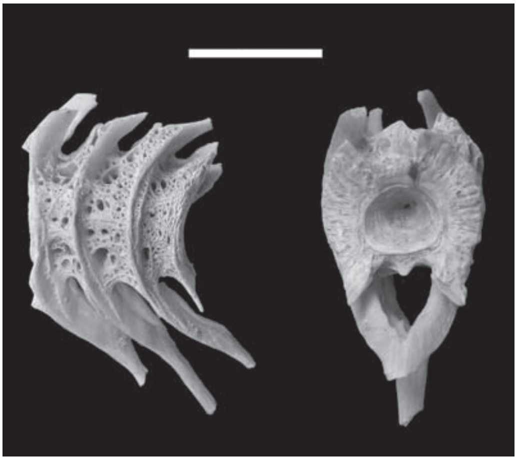

Figure 18.6. Three fused cod precaudal vertebrae. Scale=1 cm.

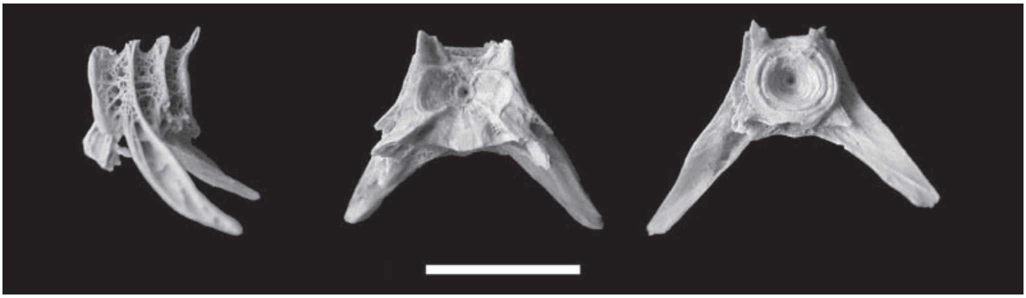

Figure 18.7. Three fused cod precaudal vertebrae. Scale=1 cm.

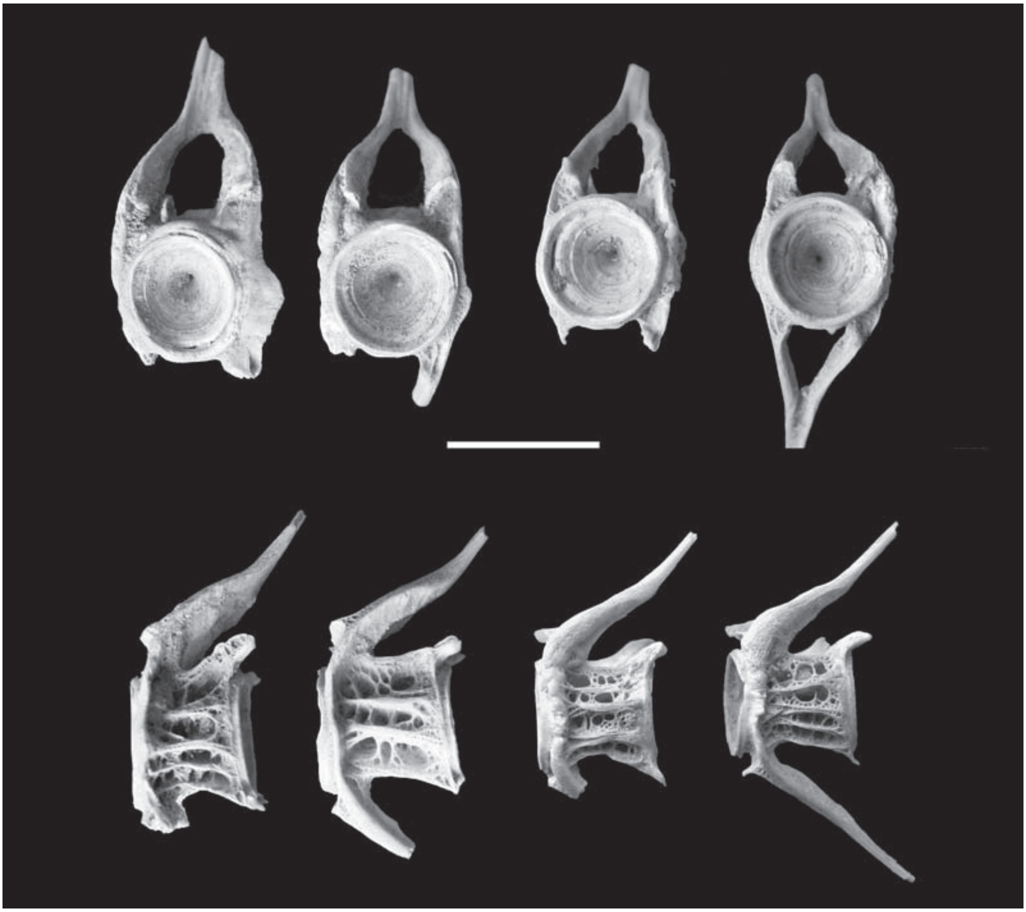

Figure 18.8. Four cod caudal vertebrae showing osteophyte formation. Scale=1 cm.

18.4 Causes for skeletal deformations in the literature

Skeletal anomalies in crania and vertebrae have been reported in several studies. The studies have mostly been conducted on commercially cultured fish. Skeletal abnormalities are often reported only if they hinder the mass production of fish, *e.g.* fish with deformities in the vertebrae must be manually filleted, increasing costs of production (Branson and Turnbull 2008). The lack of studies on fish without commercial importance makes the study of anomalies in pre-modern fish challenging.

The causes of skeletal deformities seem to be a complex mixture of environment, nutritional and genetic factors such as breeding. These all affect growth, development and survival. The diagnosis of lesions found in fish from archaeological contexts is difficult because different factors may lead to similar results. Skeletal changes may occur for a number of reasons and cause various anomalies in different species (Boglione and Costa 2011, 263–279). Sensitivity to pathogenic factors may differ depending on the life cycle of the fish (Mazurais *et al*. 2009). Some factors can be manifested in certain parts of the skeleton of some species but not in others (Koumoundouros 2010). Pathogenic effects on skeletal elements of the same individual can also vary (Fernández and Gisbert 2011). Changes in the skeleton seem to derive from vitamin and mineral deficiency and microbes. Genetics may also contribute to an increased risk of deformities (Boglione and Costa 2011, 251). Some families (*e.g.* Clupeidae, Salmonidae and Cyprinidae) have acellular bones with osteocytes in contrast to Percidae who lack osteocytes and cannot store calcium, resulting in difficulties in repairing fractures (Moss 1965).

The most common deformations in the vertebrae of farmed fish are kyphosis, lordosis, scoliosis and plathyspondyly (short caudal fin, shortening of vertebrae) and fused vertebrae. Cranial deforimities, such as reduced dentary, bent dentary/cross bite, cleft palate and gill–cover shortening (Hoole *et al*. 2001; Lall 2010, 227) have also been noted. Bony fish have no medullary canal or haversian system which means that some inflammatory conditions, such as osteomyelitis, cannot develop (Roberts 2012, 138). Ribs and vertebrae with osteomas have been documented. In largehead hairtail (*Trichiurus lepturus*) populations several osteomas in the neural and haemal arch of the dorsal vertebrae were observed (Lima *et al*. 2002). There are no descriptions of tumors causing scoliosis or similar deformities in the vertebra (Grimmet *et al*. 2011, 222). Vertebral deformities are prevalent and mostly associated with excessive or insufficient amounts of vitamins (A, D, C, E and K) and minerals (calcium, phosphorus, zinc, selenium and magnesium) in farmed fish (Lall 2010, 227). Deficiencies in nutrition can deform cartilage, which leads to distorted bone when osteoids replace the cartilage (Kitamura 1965, Poston 1967, Halver 1969, Soliman *et al*. 1986). The demand for vitamins in fish species is small but might increase during periods of growth and spawning (Hardy 2012, 407). Although *hypervitaminosis* is well-known in modern farmed fish, it is a most unlikely cause of deformities in free-living, pre-modern populations.

Vitamin A has different active forms, of which *retinol* (A1) is found in saltwater fishes, and *retinol* and *dehydroretinol* (A2) can be found in freshwater fishes. Vitamin A deficiency causes, among other things, poor growth, erosion of the caudal fins and shortening of the operculum and gills (Kitamura *et al*. 1967, 1126; Aoe *et al*. 1969, 462–463;

Moren *et al*. 2004). Vitamin C deprivation can lead to conditions such as lordosis and scoliosis in the spine, stress fractures, and deformation to the operculum and gills. Periods of insufficient amounts of vitamin C can cause brittle vertebra vulnerable to fractures (Halver 1989; Roberts 1989). The channel catfish (*Ictalurus punctatus*) has been reported to suffer from 'broken back syndrome' with symptoms such as fractures in the spine and reduced growth (Meyer 1975; Halver 1989; Roberts 1989) linked to C *hypovitaminosis*. This catfish species has acellular bone which heals with difficulty (Hardy 2012, 415).

Changes in the skeleton may also be caused by three minerals: phosphorus, zinc and manganese. Phosphorus is one of the few minerals that fish can obtain from the water. Phosphorus deficiency has been reported in some fish farms where the nutrition was primarily based on fishmeal. The fish suffered from anorexia, dark colouring, and deformation of the head, ribs and vertebrae (Ogino and Takeda 1976; Skonberg *et al*. 1997). A combined deficiency in phosphorus and vitamin C has been reported to cause deformations in Atlantic salmon (*Salmo salar*). Low mineral and vitamin intake in smolts (when the need for high-energy diet increases) seems to be a key factor in hampering ossification, leaving the bones rubbery. Some specimens were reported having a coiled form of the spinosus processes and even a jaw locked open, so-called 'screamers' (Roberts et al. 2001). Other specimens were reported with collapse of the precaudal or caudal vertebra followed by kyphosis or scoliosis. In such fish, the spine acquires a twisted or curled form and can also be covered with mineralised plaques (Sullivan *et al*. 2007). The deformity is caused by a diminishing mineral content together with movement of the musculature (Lall 2010, 228).

Deformities in the cranium and disturbance in growth (dwarfism) can be caused by deficiency in zinc and manganese (*e.g*. Ketola 1979; Satoh *et al*. 1983; Yamamoto *et al*. 1983; Lall 2010, 228). As with vitamins, the level of mineral content in the diet affects mostly young fishes and is primarily associated with difficulties in absorbing minerals due to high contents of ash or calcium in the diet (Hardy and Shearer 1985; Richardson *et al*. 1985). Other reported causes of lesions in the vertebrae are microbe-induced infections. Deformities in the vertebrae have been observed in rainbow trout (*Oncorhynchus mykiss*) that have survived *Infectious Haematopoietic Necrosis Virus* (IHNV) (LaPatra *et al*. 2001, 400). The bacterium *Flexibacter psychrophilus* has been associated with *cephalic pyogranulomatous osteochondritis* in intensively reared rainbow trout causing deformities in the cephalic skeleton (Ostland *et al*. 1997).

Some salmonid species and fresh water species such as pike, perch and tench (*Tinca tinca*) have been reported with an infection in the brain and spine cartilage caused by the parasite *Myxobolus cerebralis*. The condition is called the 'whirling disease'. The spores of the parasite produce necrosis in the cartilage of the skull, which then ossifies in a faulty way. Deformities can also occur as shortening of the spine, deformities in the cranium and opercular. This disease, however is rarely seen in wild populations (Halliday 1976).

There is a wide range of possible aetiologies causing deformities encountered in archaeological fish bone assemblages. Pathogens, mostly identified in intensively reared present-day fish, are summarised in Table 18.2.

Table 18.2. Anomalies and deformities in the skeleton and causes. Sources: Kitamura et al. *1967; Aoe* et al. *1969; Meyer 1975; Ogino & Takeda 1976; Ketola 1979; Satoh* et al. *1983; Yamamoto* et al. *1983; Halver 1989; Roberts 1989; Ostland* et al. *1997; Skonberg* et al. *1997; LaPatra* et al. *2001; Roberts* et al. *2001; Moren* et al. *2004; Sullivan* et al. *2007 Lall 2010.*

	Deformed crania	*Deformation in the sutures of the crania*	*Deformation of dentary region*	*Shortening of opercular bone*	*Stress fracture in opercular bone*	*Deformation of opercular bone*	*Deformation of spine*	*Fractures in the spine*	*Fractures in vertebra*	*Scoliosis*	*Lordosis*	*Kyphosis*	*Deformation of ribs*	*Deformation of the skeleton*	*Reduced growth*
Vitamin A				x											x
Vitamin C		x	x		x	x		x	x	x	x				x
Phosphorus	x		x				x			x		x	x		
Zinc	x														x
Manganese	x														x
IHNV							x								
Flexibacter psychrophilus														x	
Myxobolus cerebralis	x		x			x				x		x		x	x

18.5 Discussion

Identifying aetiologies for the lesions found on the Kastelholm fish bones is difficult, as most of the literature deals with farmed fish rather than wild populations. Brackish water in the Baltic Sea may contribute to skeletal malformation, although these fish were likely adapted to diverse salinity. More likely candidates causing the anomalies are vitamin and mineral deficiency.

The general explanation for fused vertebrae is old age, although such symptoms may also indicate genetic predisposition or even parasitic infection. Any of these pathogens could be the cause of the excess bone formation in the cod vertebra and on the joint of the opercular bone.

The possible osteomas on pike bones could be caused by a number of reasons and could be added to the list of lesions caused by vitamin and mineral deficiency, likewise the anomaly in the hyomandibular bone of the pike. Another plausible explanation for the hyomandibular lesion is a healed fracture, as the bone is involved in suspending

the jaws of predatory fish. This could be indicated by the form and smoothness of the lesion's surface.

The challenge with using the current literature in papaleopathological analyses is that it is focused on fish effected by modern farming industry. Vitamins and minerals also seem to cause unspecific abnormalities in the fish skeleton, but there may also be explanations that the current literature does not cover.

18.6 Conclusions

Fifteen anomalous specimens were identified among seven thousand fish bones from the site of Kastelholm in the Baltic Sea. All specimens originate from adult individuals and were hand-collected. The use of only 10 mm mesh sieves have biased the recovery. Due to the small sample size from the site, no large-scale patterns could be outlined, although the observed bone lesions occurred on the remains of the most commonly identified species.

Although the large body size and old age of specimens may be a predisposing factor for skeletal anomalies, nutritional conditions and other forms of environmental stress may also contribute to the documented changes in fish retrieved from archaeological contexts, pre-dating large scale fish farming enterprises.

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Animals have always been integral to culture. Their interaction with humans has intensified since the onset of domestication resulting in higher incidences of animal disease due to human intervention. In the meantime, human care began counterweighing pressures of natural selection, which reduces morbidity among wild animals.

In times pre-dating the written veterinary record animal disease can be traced only by analysing pathological symptoms on excavated animal remains. This volume is a collection of studies in this discipline, animal palaeopathology. Its international team of experts offers reviews of animal welfare at ancient settlements from both prehistoric and historic periods across Eurasia. Several chapters are devoted to the diseases of dog and horse, two animals of prominent emotional importance in many civilizations. Curious phenomena observed on the bones of poultry, sheep, pig and even fish are discussed within their respective cultural contexts. Many poorly healed bones are suggestive of neglect in the case of ordinary livestock. On the other hand, a great degree of compassion may be presumed behind the long survival of seriously ill companion animals.

In addition to furthering our better technical understanding of animal disease in the past, this volume also mirrors the diversity of human attitudes towards animals during our millennia-long relationship. Some animal bones show signs of extreme cruelty but others also reveal the great attention paid to recovering animals. Such attitudes tend to be a largely hidden yet characteristic aspect of how people have been relating to the surrounding world and, ultimately, to each other.

LÁSZLÓ BARTOSIEWICZ is Professor in Osteoarchaeology at the University of Stockholm. He was granted a Senior Doctorate in Animal Science by the Hungarian Academy of Sciences in 2000. His research concerns animal–human relationships as shown by archaeological finds from various periods.

ERIKA GÁL is a Senior Research Fellow at the Hungarian Academy of Sciences Budapest. She completed her PhD in Palaeontology at the University of Bucharest in 2002. Her research focuses on the study of animal remains from archaeological sites in the Carpathian Basin with special interest in bird bones.

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